Path loss calculation for a surface duct statistics

I. Sirkova[1]

Abstract – **This report applies recently published tropospheric ducts statistics for the region of Bosporus to the simulation of path loss for WCDMA FDD DL frequency band. The ducts parameters from the statistics are used as input to the parabolic wave equation method known to provide accurate path loss calculations in complex environments. Seasonal, monthly and daytime/nighttime variations of the path loss are presented. The results may be used for a preliminary assessment of coverage and possible interferences for the studied region and frequency band.**

Keywords – **Microwave propagation modelling, Duct statistics, Parabolic equation.**

I. INTRODUCTION

To account for the propagation conditions in coastal and maritime regions the propagation prediction models used need as input, besides other quantities, the meteorological parameters defining the tropospheric refractivity, especially when it differs from the standard troposphere case. The most severe deviation in refractivity from the standard conditions is the formation of tropospheric duct. The effect of ducted propagation on communications links has been studied in [1]-[4]. The difficulties in producing continuously *in situ* meteorological parameters measurements have lead to the use of global [5], [6] or local [7] climatology statistics in order to obtain the duct parameters. In [7], a two year statistics on surface duct formation over Istanbul has been reported. This area is rich in trapping layers forming different duct types: the annual percentage of surface duct occurrence is 31%, [7], the global seasonal statistics in [6] exhibit ducting occurrences for all type of ducts with averaged frequencies peaking at 60% in summer late afternoon. The availability of even short-time, but reliable, duct statistics has determined the interest in applying it to assess the microwave path loss variations due to anomalous tropospheric conditions for this region. In the present work, the duct parameters derived from [7] are used as input to the parabolic equation method known to provide accurate path loss calculations under complicated propagation conditions [8]-[10]. This report is related to [11] and follows the reference scenario relevant to coastal and maritime regions defined there.

The data reported in [7] are based on radiosonde measurements recorded at a meteorological station situated near Bosporus strait, Istanbul. The duct statistics provided refers particularly to the surface ducts for which the necessary parameters to reconstruct the modified refractivity M profiles using bi-linear model are the duct thickness Z_d and the duct strength ΔM (or M-deficit), [11]. Other types of ducts, surface-based or elevated, [11], [7], are not included in the statistics of [7]. Also, there is no differentiation of the evaporation ducts from the other surface ducts. Among the variety of data reported in [7] the present study makes use of the monthly variation of Z_d and ΔM (mean values extracted from Fig. 4, [7]) during the year, monthly variation of the nighttime and daytime mean values of the same parameters (Fig. 5 a) and c), [7]) and their seasonal variation for stable tropospheric conditions (extracted from Fig. 8 a) and b), [7]). The stable troposphere has been chosen because, following the reported statistics, the surface ducts occurrence has been higher under stable conditions than under unstable ones.

II. PATH LOSS CALCULATIONS

The reconstructed through the bi-linear model M-profiles serve as input to the Advanced Propagation Model (APM) routines, used to compute the path loss. Those routines are based on a hybrid ray optics/PE method [12] and account simultaneously for microwave diffraction, refraction and scattering, thus providing accurate path loss computation. The initial field required to start the APM is provided by horizontally polarized Gaussian beam source with pattern factor given by (1) where θ_0 and θ_s are the half power beamwidth and the antenna elevation angle. Perfect conductivity of the ground/sea is assumed. The results are presented in the form of path loss (PL, in dB), equation (2), versus range for a fixed height.

$$F(\theta) = \exp\left[\frac{\ln(0.707)(\theta-\theta_s)^2}{\left(\theta_0/2\right)^2}\right], \qquad (1)$$

$$PL = 20\log\left(\frac{4\pi r}{\lambda}\right) - PF, \qquad (2)$$

In (2) λ is the free-space wavelength, r is the distance between the corresponding points and PF is the pattern propagation factor defined as the square of the ratio of the electric field amplitude E received at a given point under specific conditions to the amplitude of the electric field E_0 received under free-space conditions with the beam of the transmit antenna directed toward this given point. In this work, we used two carrier frequencies, f_{DLmin}=2112.4 MHz and f_{DLmax}=2167.4 MHz, situated at the two ends of the UMTS WCDMA-FDD downlink band. Ducting is the most important short-term interference mechanism over water and in flat coastal areas due to the increased propagation range. The possible interference on other, geographically close links

---

[1] Irina Sirkova is with the Institute of electronics, Bulgarian Academy of Sciences, 72 Tzarigradsko chaussee Blvd, Sofia 1784, Bulgaria, E-mail: irina@ie.bas.bg

is more likely to come from the base station; that is why the downlink band has been chosen. The most samples are for f_{DLmin}, the higher the frequency the more affected it will be by the ducting. The reported results are for transmitter antenna height Z_t=30 m, θ_0=5^0, θ_s=0^0 and fixed height Z_r=20 m.

III. RESULTS AND DISCUSSION

Fig. 1 shows comparison between path loss variations obtained for M-profiles based on monthly mean values of the surface duct parameters. It is to be noted that in this case Z_r is always "submerged" within the duct; the same is true for Z_t except for January, March and May. For distances greater than 6 km path loss under ducting differs significantly from month to month and may exceed or be lower than the standard troposphere case reaching a difference of more than 30 dB for September and r=7.8 km. September is characterized by moderate Z_d but it is with strongest ΔM. Due to the bi-linear profile of M, months with similar ratio $\Delta M/Z_d$ demonstrate similar path loss behavior. Fig. 2 depicts path loss variations for seasonal mean surface ducts parameters. For summer and autumn months path loss variations compared to standard tropospheric case exceed 15 dB for some ranges (r=9.8 km, r=12 km, respectively). Fig. 3 compares path loss variations for the worst summer case for which the pair Z_d-ΔM is available for f_{DLmin} and f_{DLmax}. The two frequencies are compared also for September, a month with strong values of ΔM. The behavior of path loss variations for this particular scenario for the two frequencies is similar. It is to be noted that for different scenario (different values of Z_t, Z_r and/or Z_d-ΔM) the differences in the two end of DL band may be grater. Figs. 4 and 5 compare path loss variations obtained for M-profiles for daytime and nighttime mean duct parameters for winter/spring months and summer/autumn months, respectively. Nighttime/daytime path loss differences reach significant values: 9 dB for May (r=9.8 km), 10 dB for September (r about 12 km), more than 12 dB for October (r=9.5 km).

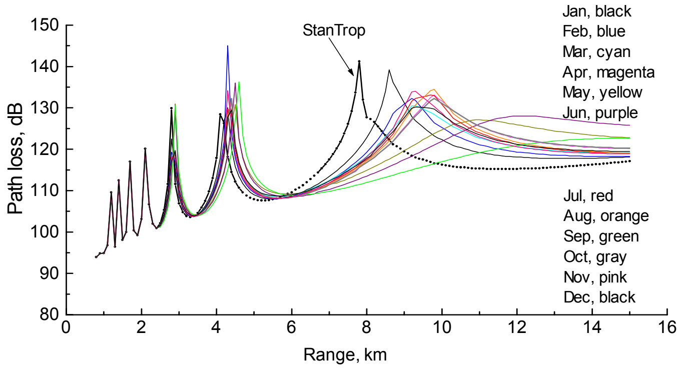

Fig. 1 Comparison between path losses obtained for M-profiles based on monthly mean values of duct parameters.

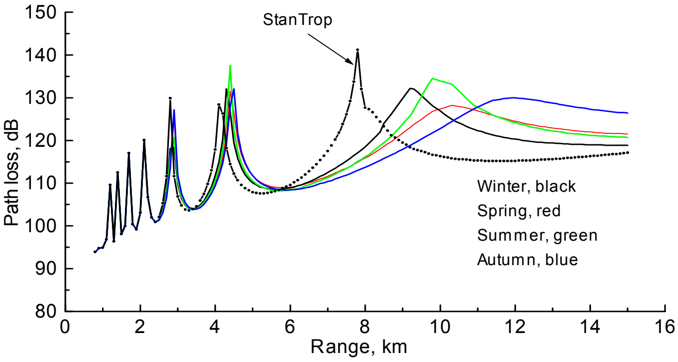

Fig. 2 Comparison between path losses obtained for M-profiles for seasonal mean duct parameters.

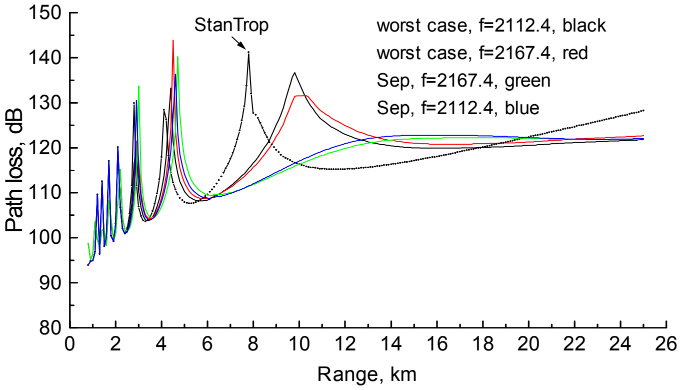

Fig. 3 Comparison between f_{DLmin} and f_{DLmax} path losses obtained for M-profiles for the worst summer case (Z_d=70 m, ΔM=12 M-units) and for September mean duct parameters.

IV. CONCLUSION

The presented study is limited to the effect due to surface ducts only. For more detailed study a long-term duct statistics differentiating between different duct types and accounting for range-dependent duct thickness and strength is needed. The last is required by the mixed land-sea-land path in the area. Finally, the duct statistics reported in [7] tends to underestimate the ducts occurrence due to the limitations in the resolution of the radiosonde data used. Nevertheless, even though tentative, the presented study shows: a) the path loss differences of scores of dB due to surface ducting will affect the link budget and increase the requirements to the WCDMA power control range; b) how the duct statistics should be used: when predicting the PL, use of monthly mean values for the duct parameters rather than annually averaged values is needed. A further differentiation between nighttime/daytime cases may also be required to account for specific climatic characteristics and influences.

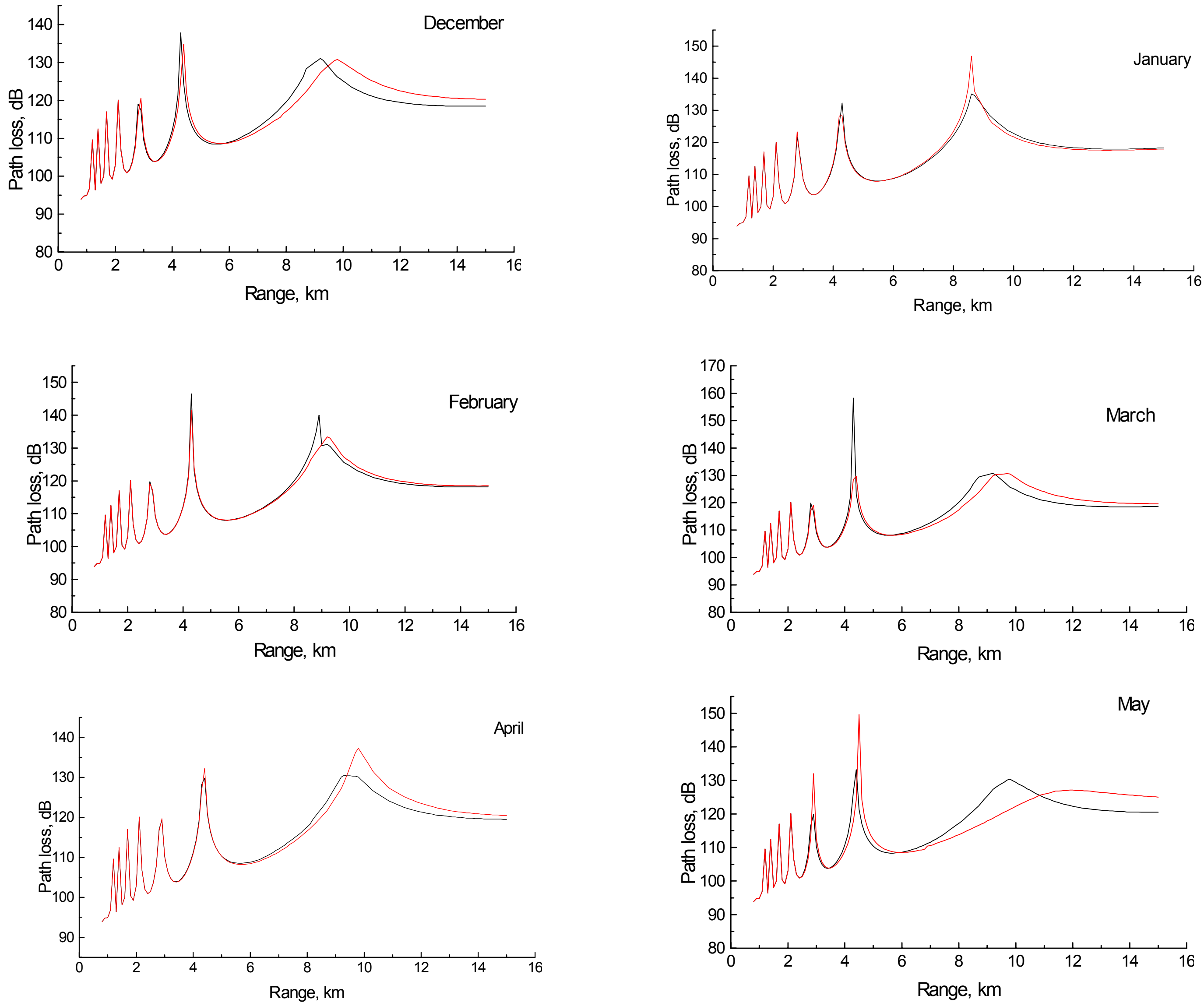

Fig. 4 Comparison between path losses obtained for *M*-profiles for daytime (red) and nighttime (black) mean duct parameters for winter and spring months.

ACKNOWLEDGEMENT

This work was partially supported by Action 2100 of the European program COST. The author is grateful to the SPAWAR Systems Centre, San Diego, USA, for making available the APM code.

REFERENCES

[1] A. Kerans, A. S. Kulessa, E. Lensson, G. French, G. S. Woods, “Implications of the evaporation duct for microwave radio path design over tropical oceans in Northern Australia”, Proc. WARS (Workshop Applications of Radio Science), 4 p., Leura, Australia, 20-22 Feb 2002.

[2] M. J. Willis, K. H. Craig, “Results from a Long Term Propagation Measurement Campaign”, 2nd EuCAP, pp. 1-8, Edinburgh, UK, 11-16 Nov 2007.

[3] I. Sirkova, M. Mikhalev, “Parabolic-equation-based study of ducting effects on microwave propagation”, J. of Microw. Opt. Technol. Lett., vol. 42, no. 5, 2004, pp. 390-394.

[4] D. Siddle, E. M. Warrington, S. Gunashekar, “Transhorizon propagation at 2GHz”, 4th COST 2100 MCM, 13 p., Wroclaw, Poland, 6-8 Feb 2008.

[5] A. von Engeln, J. Teixeira, “A Ducting Climatology derived from ECMWF Global Analysis Fields”, J. Geophys. Res., vol. 109, no. D18, 2004.

[6] Ph. Lopez, “A 5-year 40-km Resolution Global Climatology of Super-refraction for Ground-based Weather Radars”, J. of

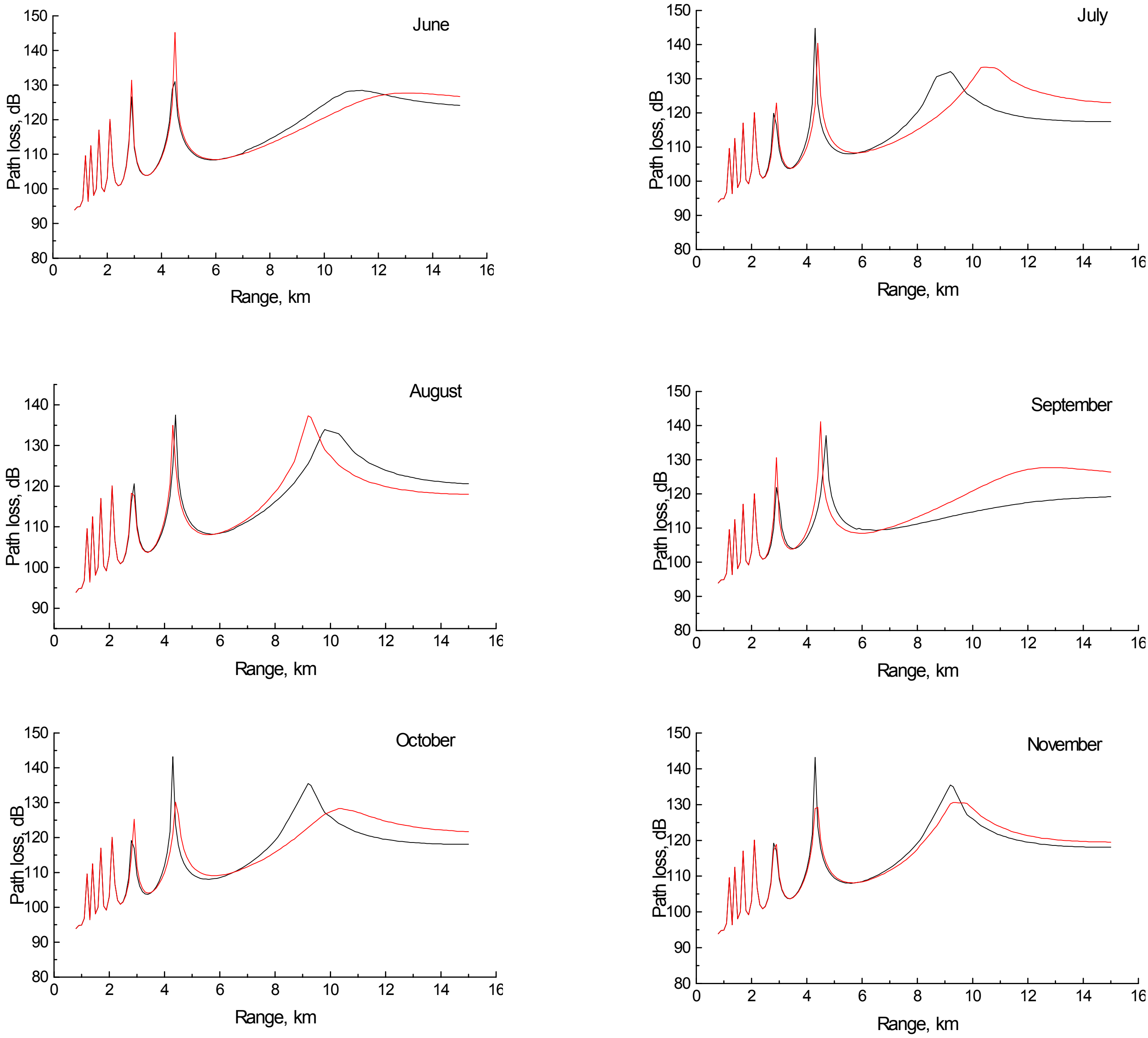

Fig. 5 Comparison between path losses obtained for *M*-profiles for daytime (red) and nighttime (black) mean duct parameters for summer and autumn months.

Applied Meteorology & Climatology, doi: 10.1175/2008JAMC1961.1, 2008.

[7] S. S. Mentes, Z. Kaymaz, “Investigation of Surface Duct Conditions over Istanbul, Turkey”, J. of Applied Meteorology & Climatology, vol. 46, pp. 318-337, 2007.

[8] M. Levy, *Parabolic equation methods for electromagnetic wave propagation*, IEE electromagnetic waves series 45, UK, 2000.

[9] A. E. Barrios, K. Anderson, G. Lindem, “Low Altitude Propagation Effects - A Validation Study of the Advanced Propagation Model (APM) for Mobile Radio Applications”, IEEE Trans., Antennas &. Prop., vol. 54, no.10, pp. 2869-2877, 2006,.

[10] I. Sirkova, M. Mikhalev, “Parabolic Wave Equation Method Applied to the Tropospheric Ducting Propagation Problem – a Survey”, Electromagnetics, vol. 26, no. 2, pp. 155-173, 2006.

[11] I. Sirkova, “Proposal for a reference scenario relevant to coastal and maritime regions”, 4th COST 2100 MCM, 6 p., Wroclaw, Poland, 6-8 Feb 2008.

[12] A. E. Barrios, W. L. Patterson, R. A. Sprague, Advanced Propagation Model (APM). Computer Software Configuration Item (CSCI) Documents. *SSC SD TD 3214*, 2007.