Experimental validation of second order diffraction coefficients for computation of path-loss past buildings

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Abstract— **Electromagnetic fields diffracted past buildings are not correctly predicted by ray-tracing methods using first order diffraction coefficients. Correct results are obtained by using second order diffraction coefficients as demonstrated by the experimental validation provided and discussed herein.**

Keywords— **Ray tracing, Geometrical Theory of Diffraction, Radio Propagation, Measurements.**

I. Introduction

ACCURATE path-loss predictions are important to plan the wireless networks that support the exchange of both voice and data communications. Many methods have been developed to assess path-loss; however, those that exploit a detailed geometrical description of the environment under study lead to more precise results. In particular, buildings inside urban environments were originally approximated using knife edges [1]; however, better results are achieved by approximating buildings with rectangular shapes [2]. When a detailed geometry is used, ray-tracing methods are easier to apply. Here ray-tracing methods using first and second order diffraction coefficients to compute the path-loss after a building are compared.

II. The method

A ray-tracing method is applied to evaluate the field diffracted past a rectangular building in a two-dimensional case where the trajectories propagate in the vertical plane containing both the transmitter and receiver antennas. This investigation proves that field computations for propagation past rectangular buildings using ray-tracing methods are not correct if diffraction is only accounted for using the first order uniform theory of diffraction (UTD) [3] coefficients. The method to obtain correct results is the use of second order diffraction coefficients . Fig. 1 shows an ordinary situation of diffraction past a building, case A, and a situation of grazing incidence, case B. In both cases, the field at R_x cannot be computed using the product of first order diffraction coefficients at P and Q. The problems associated with the use of first order diffraction coefficients are solved by introducing into the computation the second order diffraction coefficients [4], [5] to evaluate the fields diffracted by a double-wedge structure, such as the buildings of Fig. 1.

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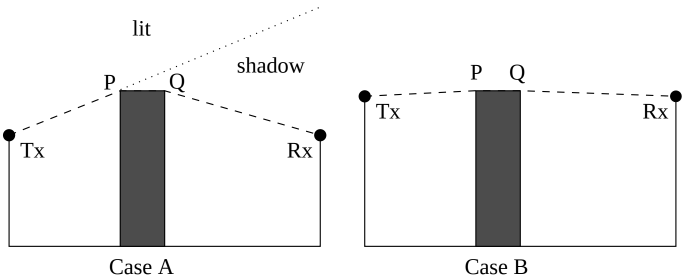

Fig. 1. Geometry

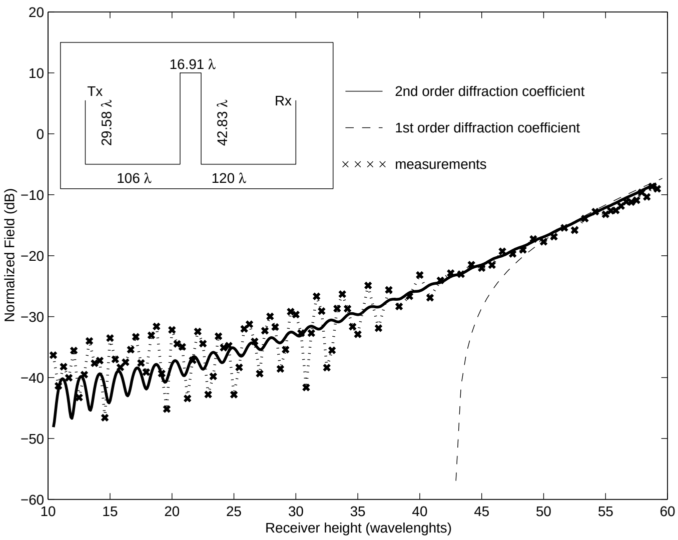

Fig. 2. Case A: soft polarization. Mean error: 2.90 dB, standard deviation 2.59 dB.

III. Results

The path-loss for cases A and B have been computed using both first and second order diffraction coefficients, for soft and hard polarization, assuming that the building and the terrain are perfect electric conductors. Measurements to validate the use of second order diffraction coefficients were taken, inside an anechoic chamber, on a copper scaled model of a rectangular building and the terrain at the frequency of 25 GHz. The transmitter T_x was kept at a constant height while R_x was moved vertically at small increments of a fraction of the wavelength. Reflections from the terrain were included. The results for case A are shown in Fig. 2 for the case of soft polarization. The measurements and the computation using second order diffraction coefficients are in good agreement, as indicated by a mean

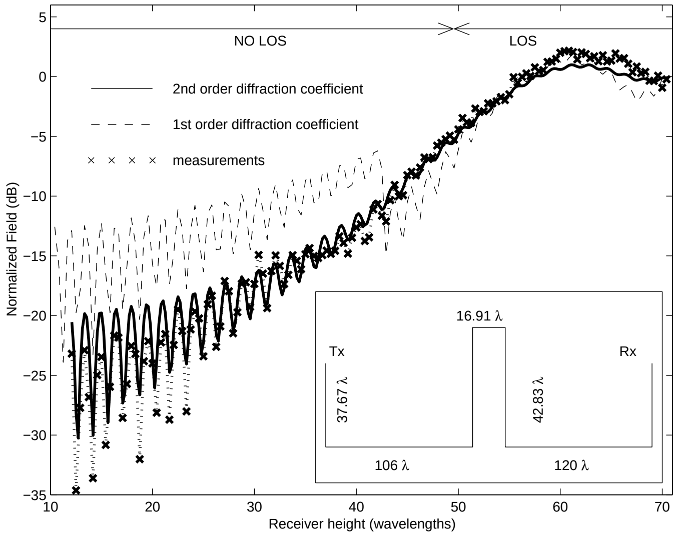

Fig. 3. Case A: hard polarization. Mean error: 1.12 dB, standard deviation 1.23 dB.

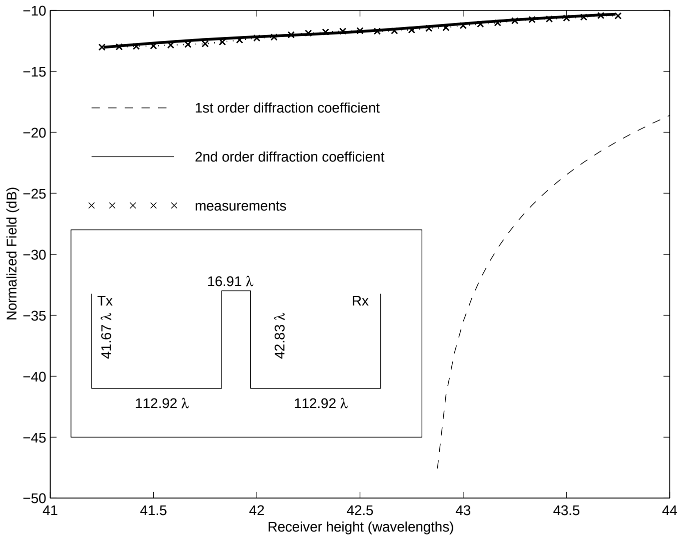

Fig. 4. Case B: soft polarization. Mean error: 0.14 dB, standard deviation 0.08 dB.

error of 2.90 dB and a standard deviation of 2.59 dB. In contrast, the computation using first order diffraction coefficient is definitely wrong. The hard polarization result for case A is shown in Fig. 3, where the agreement is even better with 1.12 dB the mean error and 1.23 dB the standard deviation. The prediction obtained using the first order theory is again not correct when the receiver enters the shadow zone. Fig. 4 shows the comparison for case B, grazing incidence, when the polarization is soft. The agreement for the second order theory is now expressed by a mean error of 0.14 dB and a standard deviation of 0.08 dB. Similar to the soft polarization case A, Fig. 2, the first order theory is not correct for this situation either. Finally, the hard polarization for case B is shown in Fig. 5 where the mean error between the curves is 0.36 dB and the standard deviation is 0.27 dB.

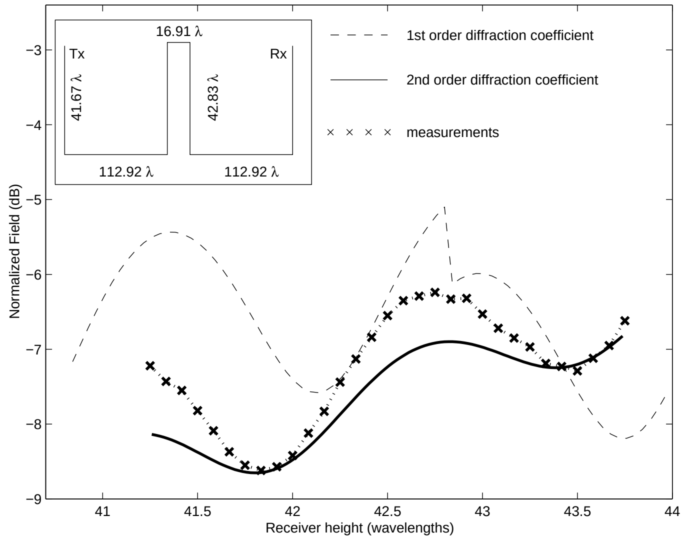

Fig. 5. Case B: hard polarization. Mean error: 0.36 dB, standard deviation 0.27 dB.

IV. Conclusion

These comparisons show that the use of first order diffraction coefficients leads to incorrect results even for the simple cases shown in Fig. 1. In particular, soft polarization provides the worst results with first order diffraction coefficients. The introduction of the second order diffraction coefficients removes these errors as proven by the various comparisons with the measurements that show a very good agreement for all the cases analyzed. Therefore, ray-tracing methods for propagation prediction should consider the introduction of second order diffraction coefficients, or equivalent methods, to guarantee the appropriate computation of the diffracted fields. Actual buildings are not made of perfect electrical conductor materials, but this can be accounted for using impedance surfaces as described in [6].

References

[1] J. Walfisch and H. L. Bertoni, "A theoretical model of UHF propagation in urban environments," *IEEE Trans. Antennas Propagat.*, vol. 36(12), pp. 1788–1796, Dec 1988.

[2] D. Erricolo and P. L. E. Uslenghi, "Knife edge versus double wedge modeling of buildings for ray tracing propagation methods in urban areas," in *Digest of National Radio Science Meeting*, Boulder, CO, USA, Jan 1998, p. 234.

[3] R. G. Kouyoumjian and P. H. Pathak, "A uniform geometrical theory of diffraction for an edge in a perfectly conducting surface," *Proc. IEEE*, vol. 62(11), pp. 1448–1461, Nov 1974.

[4] M. Albani, F. Capolino, S. Maci, and R. Tiberio, "Diffraction at a thick screen including corrugations on the top face," *IEEE Trans. Antennas Propagat.*, vol. 45(2), pp. 277–283, Feb 1997.

[5] M. Albani, P. Piazzesi, F. Capolino, S. Maci, and R. Tiberio, "Shielding effect of a thick screen with corrugations," *IEEE Trans. Electromagn. Compat.*, vol. 40(3), pp. 235–239, Aug 1998.

[6] D. Erricolo and P. L. E. Uslenghi, "Two-dimensional simulator for propagation in urban environments," *IEEE Trans. Veh. Technol.*, vol. 50(4), pp. 1158–1168, July 2001.