WAVE-OPTICAL SIMULATION OF RADIO PROPAGATION IN A CITY

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Abstract

The scenario of radio propagation in a skyscraper city district is simulated by means of the multiple phase screen techniqe (or split-step Fourier algorithm) solving the parabolic approximation of the Helmholtz equation. Diffraction and interference effects are efficiently described by this method. The simulations are performed for transmitter frequencies at VHF, UHF, and L-band. Light and shadow effects in a city district area of around 200 x 800 m are presented for various transmitter positions and spatial divergences of the electromagnetic fields. Comparisons to ray tracing will be carried out.

1. Introduction

High computation speeds and the fast Fourier transformation are the foundation for application of the MPS (multiple phase screen) technique to either forward or backward propagation of wave fields.

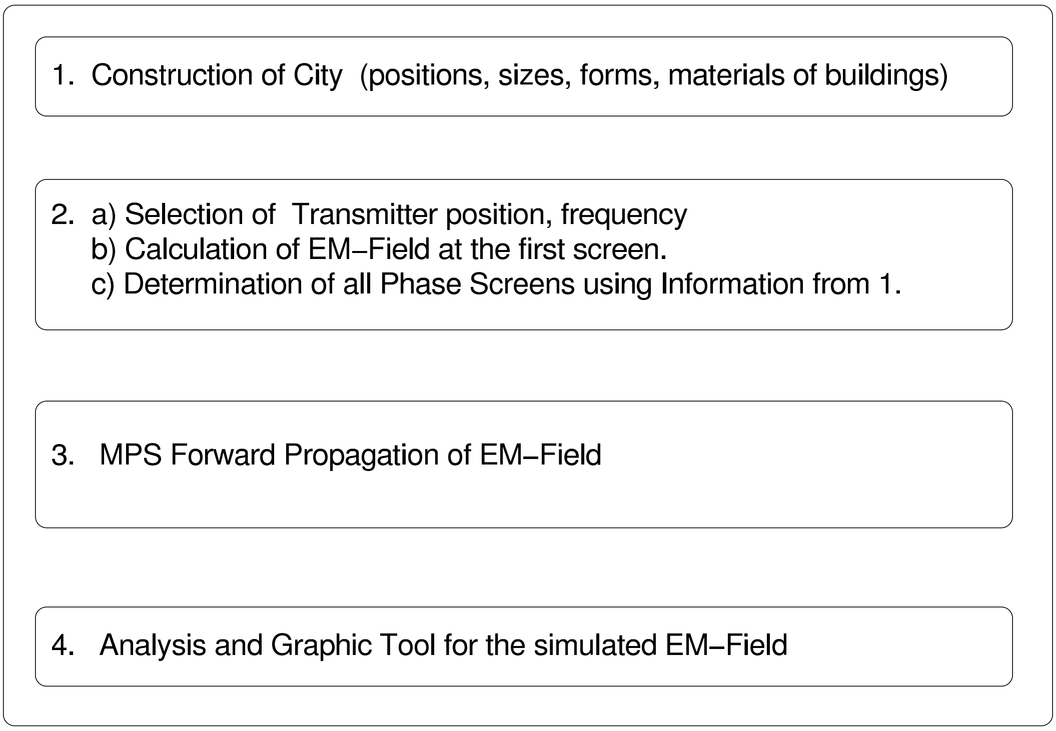

Figure 1: Scheme of the organization of a wave-optical simulation for radio propagation in a city.

The MPS technique can be described in a simple manner: the medium is approximated by thin screens containing the phase path excess and/or absorption loss which would occur in reality between the screens. At each screen position the corresponding phase path excess or absorption loss is added to the incoming wave front and wave amplitude respectively. The MPS technique comes into some trouble if waves are reflected into backward direction during the forward propagation process.

Applications include propagation of seismic waves [1], ocean acoustic waves [2], atmospheric waves [3], light [4], laser beam [5], HF radio waves in the ionosphere [6], GPS signals [7], and

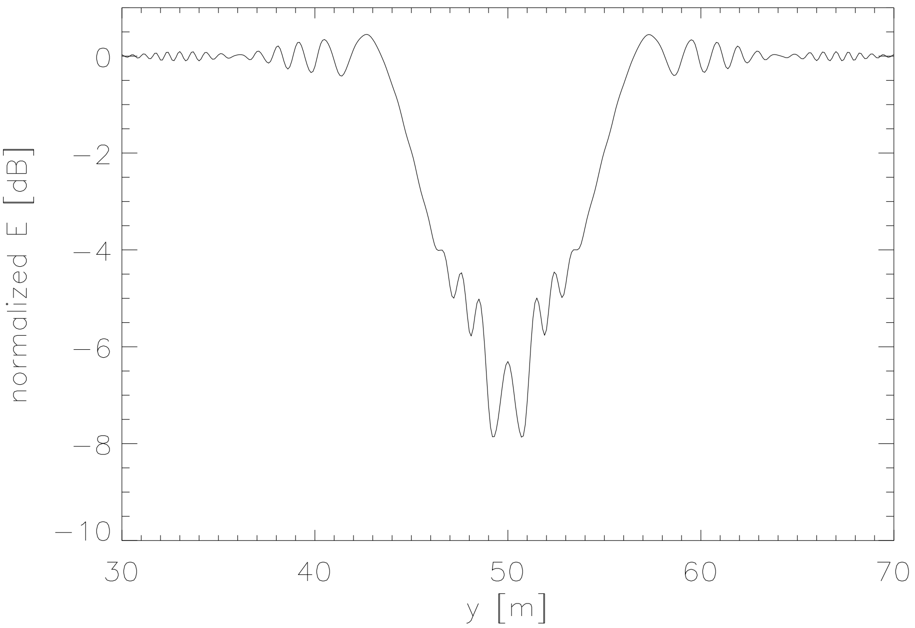

Figure 2: Normalized electric field strength along a line at the ground and across the radio shadow zone of a round tower (19 m high tower with a radius of 5 m). The horizontal distance of the line from the center of the tower is 15 m. Elevation angle of the 1 GHz radiation is around 55°. Radiation is in x-direction.

UHF/VHF radio propagation over terrain in the lower troposphere [8]. Wave-optical simulations by means of the MPS technique are complementary to ray tracing simulations. Indeed in most cases where ray tracing calculations become difficult, wave-optical simulations provide simple solutions and vice versa. For example, ray tracing informs about signal travel time, while the MPS technique can easily handle scintillations introduced by small-scale refractive index fluctuations.

2. Organization of the Simulation

A wave-optical simulation can be easily programmed as sketched in Figure 1. Our simulation consists of four main parts: 1. construction of the city district, 2. selection of initial radio field and calculation of all phase screens, 3. forward radio propagation, 4. analysis and graphic display of simulated EM-field. The tasks 1 and 4 require the main programming efforts, while 2 and 3 are short program modules. The clear algorithmic separation of a wave-optical simulation into a few basic parts is a strong advantage compared to ray tracing which soonly requires a complex program structure and expert's knowledge (e.g., geometrical theory of diffraction).

3. Simulations and Discussion

A test simulation has been performed for a tower (cylinder with a radius of 5 m and 19 m high). This building is incorporated into the screens by assuming total absorption. The screen resolution is 10 cm. A more realistic absorption of EM-waves by buildings has been described by [9]. The incoming radiation has an elevation angle of around 55° and comes from a transmitter in 10 km height, that means the radiation field is only slightly divergent such as those of a satellite or a future stratospheric platform. Atmospheric refraction effects are not considered since the radiation is at UHF (1 GHz). Figure 2 shows diffraction effects of the radio shadow zone of the tower. The electric field strength is depicted along a line in a distance of 15 m behind the center of the tower. Figure 3 shows the electric field strength in a distance of 20 m behind the tower, indicating a significant change of normalized electric field strength and diffraction effects.

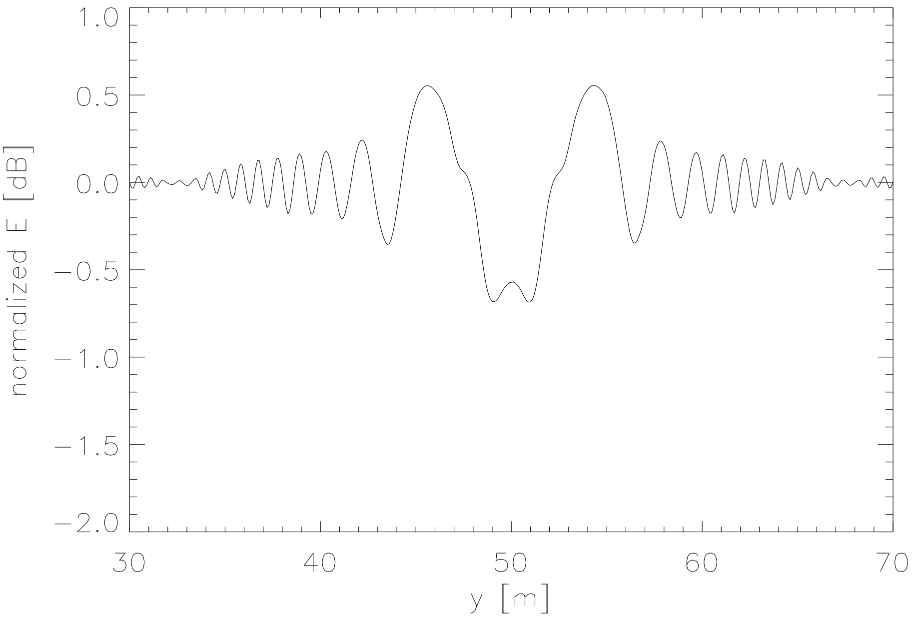

Figure 3: Same as Figure 2, but in a distance of 20 m behind the round tower.

An incorporation of various building forms and 'materials' is considered as well as an improved analysis of the complex electric field strength in the plane of the phase screen (e.g., derivation of angular spectrum). Using a screen resolution of 20 cm areas of 200 x 800 m can be handeled within a program run time of around 4 hours (on a shared work station and with the slow but high-level IDL program language).

4. Conclusions

The preliminary results are promising for further application of the MPS (multiple phase screen) technique to radio propagation studies. Especially the simple program structure is attractive since it requires less programming efforts and enables the systematic approach to a realistic simulation of radio propagation. There are several tasks which are interesting. Firstly a detailed description of diffraction and interference effects of radio fields in a city would be valuable. In view of future Ka-band communication links provided by stratospheric platforms wave-optical simulations of tropospheric water vapor effects on radio propagation are desirable.

5. Acknowledgments

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6. References

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