Modelling of Roughness Effects on Electromagnetic Waves Propagation above Sae Surface Using 3D Parabolic Equation.

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1. INTRODUCTION

This paper deals with works on radar links in a three-dimensional marine environment. Radar performances prediction represents an important phase in the radar system parameterisation. This prediction is strongly related to the electromagnetic waves propagation modelling in maritime environment. The modelling of propagation, in troposphere, requires a good consideration of meteorological parameters (principally refraction index) and a realistic characterization of wave interaction with the sea surface (taking into account of reflection and surface roughness). This article will focus on three sides. The first one is the modelling of electromagnetic waves propagation, using 3D parabolic wave equation and a Split Step Fourier algorithm. The second one consists on introduction of a hybridised method for a better taking into account of sea surface roughness in wave propagation. Finally some simulation results are presented and analyzed, for different configurations and different sea states, in a three-dimensional propagation domain.

2. ELECTROMAGNETIC PROPAGATION MODELLING USING 3D PARABOLIC EQUATION

To model electromagnetic waves propagation in a three-dimensional domain we use the 3D Parabolic waves equation technique [1][2], more easy to solve and less burdensome in terms of boundary and mesh conditions. This technique introduces hypotheses on the conventional elliptical equations of propagation to obtain a parabolic equation. To solve this equation we use a Split Step Fourier method [3][4][5]. In order to take into account the waves reflection by the bi-dimensional sea surface, the method of image source is used with the Fresnel's reflection coefficient. An absorption area is added beyond maximum height to satisfy Sommerfeld radiation conditions (towards infinity) [6][7], in this area the field is multiplied by an attenuation function (quick decrease towards zero).

3. INTRODUCTION OF SEA SURFACE ROUGHNESS IN PROPAGATION

Usually, in electromagnetic waves propagation modelling, we use perfectly flat sea surface [8][9], this approach doesn't allow the introduction of sea surface roughness effects on propagation. A more realistic model of electromagnetic waves propagation must take into account these effects. An existing method [10][11] consists to multiply the Fresnel reflection coefficients by a roughness parameter which depends on the wind speed, the roughness parameter of Rayleigh and the probability distribution of surface's heights. This method doesn't model the influence of the surface's geometry in propagation, since the sea surface is considered as flat. In order to develop a more realistic model, we introduce another method [12][13] which is based on bi-dimensional sea surface generation using sea spectrums[14] and introduction of a modified roughness parameter.

4. NUMERICAL RESULTS

In this paper, the development of a new approach for the modelling of electromagnetic waves propagation above rough sea surfaces is presented, as well as the numerical results computed for different configurations and different sea states. To generate the sea surface we use the Elfouhaily sea spectrum [14]. The results are used to show the sea surface roughness influence in electromagnetic waves propagation in a three-dimensional domain.

5. CONCLUSION AND PERSPECTIVES

The main purpose of this paper is to introduce the sea surface roughness in the simulations of electromagnetic waves propagation in a three-dimensional maritime environment. For this we introduced an original method based on generation of sea surfaces. An evolution of our works will be the introduction of different atmospheric conditions and notably the presence of evaporation ducts.

6. REFERENCES

[1] R. Janaswamy, "Path loss predictions in the presence of buildings on flat terrain: a 3-D vector parabolic equation approach", IEEE Transactions on Antennas and Propagation, Volume: 51, Issue: 8, pp 1716- 1728, Aug. 2003.

[2] R. Janaswamy, "Radiowave Propagation & Smart Antennas for Wireless Communications", Kluwer Academic Publishers, 2000.

[3] M. F. Levy, "Parabolic Equation Methods for Electromagnetic Wave Propagation", IEE Electromagnetic Waves Series, April 2000.

[4] G.D. Dockery, "Modeling electromagnetic wave propagation in the troposphere using the parabolic equation", *IEEE Trans.*, AP-36, pp. 1464-1470, 1988.

[5] H. W. Ko, J. W. Sari, M. E. Thomas, P . J. Herchenroeder, and P. J. Martone, "Anomalous propagation and radar coverage through inhomogeneous atmospheres," *AGARD Conf. Proc.*, Vol. 346, pp. 1–14, 1984.

[6] M. F. Levy, "Parabolic Equation Methods for Electromagnetic Wave Propagation", *IEE Electromagnetic Waves Series*, April 2000.

[7] M. Grábner, and V. Kvičera, "Clear-air propagation modelling using parabolic equation method", *Radioengineering* 12, pp. 50-54, 2003.

[8] K. H. Craig and M. F. Levy, "Parabolic equation modelling of the effect of multipath and ducting on radar systems", *IEE Proc. F*, Vol. 138, N° 2, pp. 153-162, April 1991.

[9] L. Sirkova, and M. Mikhalev, "Parabolic wave equation methode applied to the tropospheric ducting propagation problem : A survey", Electromagnetics, Vol. 26, Issue 2 February 2006 , pp. 155 – 173.

[10] W. S. Ament, "Toward a theory of reflection by a rough surface", *Proc. IRE,* Vol. 41, pp. 142-146, 1953.

[11] A. R. Miller, R. M. Brown and E. Vegh, "New derivation for the rough surface reflection coefficient and for the distribution of sea-wave elevations", *IEE Proc. IRE*, Vol. 131,Part H, pp. 114-116, 1984.

[12] O. Benhmammouch, A. Khenchaf, N. Caouren, "Electromagnetic Waves Propagation above Rough Sea Surface Application to Evaporation Ducts", *IGARSS 2008,* Boston July 2008.

[13] O. Benhmammouch, L. Vaitilingom, A. Khenchaf, N. Caouren, "Electromagnetic Waves Propagation above Rough Surface: Application to Natural Surfaces", PIERS 2008, Cambridge, July 2008.

[14] T. Elfouhaily, B. Chapron, K. Katsaros and D. Vandemark, "A unified directional spectrum for long and short wind-driven waves", *Oceans 97*, Vol. 102, No. C7, p. 15,781-15,796, July 1997.