ELECTROMAGNETIC WAVE SCATTERING FROM OCEAN SURFACE AT LOW GRAZING ANGLES

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1. INTRODUCTION

Scattering from rough surface in low grazing angle (LGA) has attracted much attention due to practical importance in the areas of the low-attitude/long-range radar surveillance, target tracking, communication, and navigation systems operating at low grazing conditions above the ocean surface. Conventional analytical theories of scattering from rough surface derived from some approximations, so have restricted domain of validity, such as the Kirchhoff Approximation (KA), Small-Perturbation Model (SPM), Integral Equation Model (IEM), Small Slope Approximation (SSA) and Two-Scale Model (TSM).

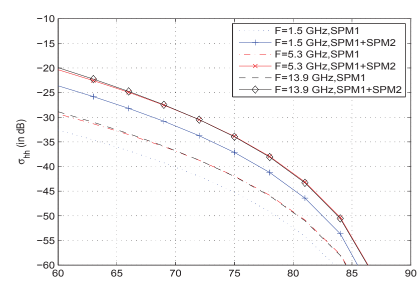
For electromagnetic scattering from ocean surface TSM can be used by splitting the surface in to two scales: a large and small one related to the incident wave. The classical bistatic TSM use the KA for the large scale and Small Perturbation Method of first-order (SPM1) for the small scale [1]. It has broader range of validity but is inaccurate for grazing angles and there is a gap in regions of validity of SPM1 and KA. Moreover, the predictions for cross-polarization in backscattering are not exact. To overcome these difficulties we study the SPM to second order [2] and develop an improved TSM by adding the second order contributions to first order of SPM. This method has first been validated on Ku-band by comparison with a first order SSA and published experimental data at non-grazing incidence for co- and cross polarizations [3, 4].

In this paper we study and analyze this improved TSM for a wide range of frequency, incident angle and under several wind conditions. Our aim is to give the configurations for which this improved model gives better estimates for grazing angles. We demonstrate this by comparing our results for backscattering case with experimental data given in [5].

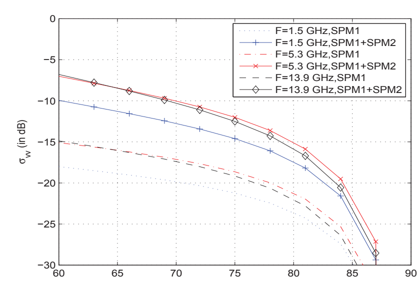
2. NUMERICAL RESULTS

We start with the numerical simulations with SPM1 and SPM2. To capture the features exhibited by sea scattering we use the roughness spectrum obtained from the Elfouhaily et al. for fully developed seas [6].

In figure 1 the backscattering scattering coefficient is calculated by letting the incident angle vary between $60°$-$90°$ for frequencies of 1.5, 5.3 and 13.9 GHz, corresponding to L-, C- and Ku-band, respectively. The wind speed is fixed to 15 m/s at a 10 meters altitude above the sea surface.



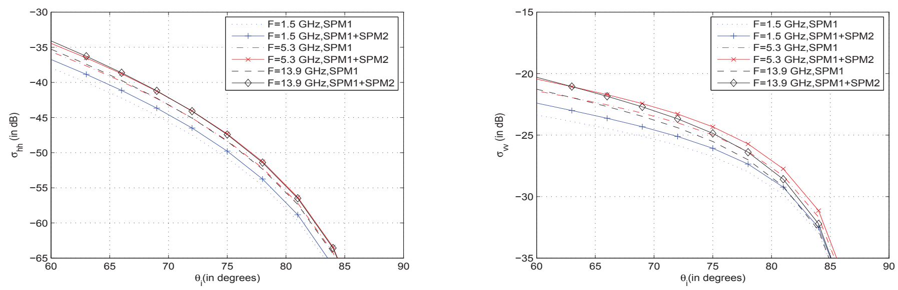
(a)HH-Polarization



(b)VV-Polarization

Fig. 1. Backscattering coefficients: Comparisons between SPM1 and SPM1+SPM2 (wind speed U10=15m/s).

In this case, we can observe that both for horizontal and vertical polarization the addition of SPM2 in SPM1 gives an improvement of 5 to 8 dB for grazing angles. Next (figure 2), we present the simulation results for a wind speed of 7 m/s at a 10 meters altitude and the other configurations same as above.



(a)HH-Polarization (b)VV-Polarization

Fig. 2. Backscattering coefficients: Comparisons between SPM1 and SPM1+SPM2 (wind speed U10=7m/s).

Again 1 to 2 dB improvement is achieved for this wind speed.

3. CONCLUSION

In general, we found that for higher wind speeds the second order scattering are stronger on grazing angles as compared to first order scattering and the contribution of SPM2 in SPM1 generates improved results on these angles. We get the same type of results for improved TSM. The results obtained from simulations with different configurations (including bistatic) will be presented in the final paper. We will also make comparisons with results obtained from other models and with experimental data available.

4. REFERENCES

[1] A. Khenchaf "Bistatic radar moving returns from sea surface", IEICE Trans. Elct., E83-C, 1827-1835, 2000

[2] L. Tsang, J.A. Kong, Scattering of Electromagnetic Waves, Vol. 3: Advanced Topics, Wiley Interscience, 2001

[3] N. Sajjad, A. Khenchaf, A. Coatanhay and A. Awada, “An improved two scale model for the ocean surface bistatic scattering, IGARSS, Boston, USA, 6-11 july, 2008

[4] N. Sajjad, A. Khenchaf, A. Coatanhay, “An improved two-scale model for the ocean surface bistatic scattering: A numerical study on C and Ku bands” article of review submitted to IEEE Transactions on Geosciences and Remote Sensing Special issue, october 2008

[5] Guinard, N.W., Daley, J.C. "An experimental study of a sea clutter model", Proc. IEEE,Vol.58, April 1970, pp. 543-550.

[6] T. Elfouhaily, B. Charpon, K. Katsaros: "A unified directional spectrum for long and short wind-driven waves", JGR, 102, 15781-15796, 1997