Radar Imaging Mechanism of the Birkenfels Wreck in the Southern North Sea

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Key words: submerged wreck, residual flow circulation, real aperture radar (RAR), normalized radar cross section (NRCS) modulation, quasi-specular scattering theory

SUMMARY

Varying tidal currents close to the sea bed cause sediment motion around wrecks leading to formation of scour holes and sand ribbons. Consequently, scouring destabilizes the position and shape of wrecks. Changing water depths above the shallowest parts of wrecks due to such sediment displacements can be crucial for the safety of ship navigation. For that reason, many wreck positions must be routinely re-surveyed. In 2008 changes occurred at 12 % of 259 investigated wrecks in German sea areas compared with the last survey. Especially lower water depths above wrecks have been measured. Therefore, basic research is still necessary to achieve new insights of wave- and current-induced sand transport in the boundary layer of the sea bed covered by wrecks and sand ribbons. Here, it will be focused on the role of active microwave remote sensing potentials for studying radar signatures at the water surface caused by submerged wrecks. The K_a band radar imaging mechanism of the submerged wreck/sand ribbon of the motor vessel (M/V) *Birkenfels* in the southern North Sea is investigated by applying the quasi-specular scattering theory and considering the capillary as well as the gravity wave ranges of the wave energy density spectrum. Multi-beam echo sounder images of the *Birkenfels* wreck and associated sand ribbons as well as other available environmental in situ data have been analyzed. The formation of sand ribbons at the sea bed and the manifestation of its radar signatures at the water surface are caused by an elliptical vortex or helical flow cell triggered by unidirectional tidal current flow interacting with the wreck. The difference of simulated and measured normalized radar cross section (NRCS) modulation as a function of the space variable is less than 31.6%. Results are presented for NRCS simulations dependent on position for different effective incidence angles, unidirectional current speeds, wind speeds, and relaxation rates.

1. INTRODUCTION

Wreck search and other investigations of submerged obstacles are special applications of hydrographic surveying. Its goal is primarily the determination of the location with the exact positioning and surveying of the shallowest water depth above wrecks and objects on the sea bed. To ensure the safety of shipping these data are indicated as symbols and abbreviations in nautical charts and Electronic Navigational Chart (ENC) data of Electronic Chart Display and Information Systems (ECDIS). More information on wreck search, wreck positions in the North Sea and Baltic Sea, historical and modern wreck search methods can be found for example under http://www.bsh.de. A wreck extending some 15 m above the sea bed in the vicinity of Sandettie Bank in the southern North Sea was undetected for 35 years (Van Riet et al. 1985). Sea areas with numerous shipwrecks can be an indicator for the occurrence of abnormal waves such as freak or rogue waves (Tamura et al. 2009). Numerous ship accidents have occurred in crossing sea conditions (Toffoli et al. 2005).

2. RADAR IMAGING MECHANISM AND RESULTS

A new view on the radar imaging mechanism of submerged wrecks associated with sand ribbons is proposed here applying the quasi-specular scattering theory (Barrick 1968) of shallow sea bottom topography considering the capillary as well as the gravity wave ranges of the wave energy density spectrum (Hennings and Herbers 2010). A transverse secondary circulation flow model is presented describing the interaction between the wreck/sand ribbon and the current field of an elliptical gyre caused by the unidirectional (tidal) current stream passing the wreck. Figure 1 presents a schematic view of the radar imaging mechanism of the submerged *Birkenfels* wreck (position: 51° 39.0' N, 2° 31.9' E) and the associated sand ribbon (McLean 1981). Results of the applied theory and the comparison of simulated and measured NRCS modulation are summarized in Figure 2.

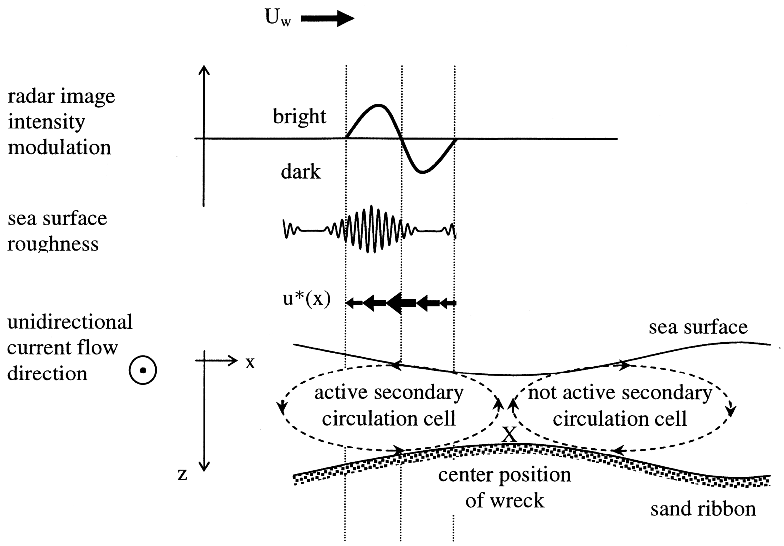

Figure 1: Schematic sketch of the unidirectional ebb tidal current flow (direction coming out of the graphic plane), cross-structure secondary circulation cells above sand waves or sand ribbons, center position of wreck marked by the capital letter X, sea surface, horizontal component of the tangential current of the secondary circulation cell $u^* = u_{perp}$ in $x = x_{perp}$-direction at the sea surface, associated sea surface roughness, and radar image intensity modulation due to accelerated and decelerated sea surface current velocities of the active secondary circulation cell. The wind direction U_w is indicated by an arrow and the left and right vertical lines indicate schematically the space range of 200 m used for simulations (Hennings and Herbers 2010).

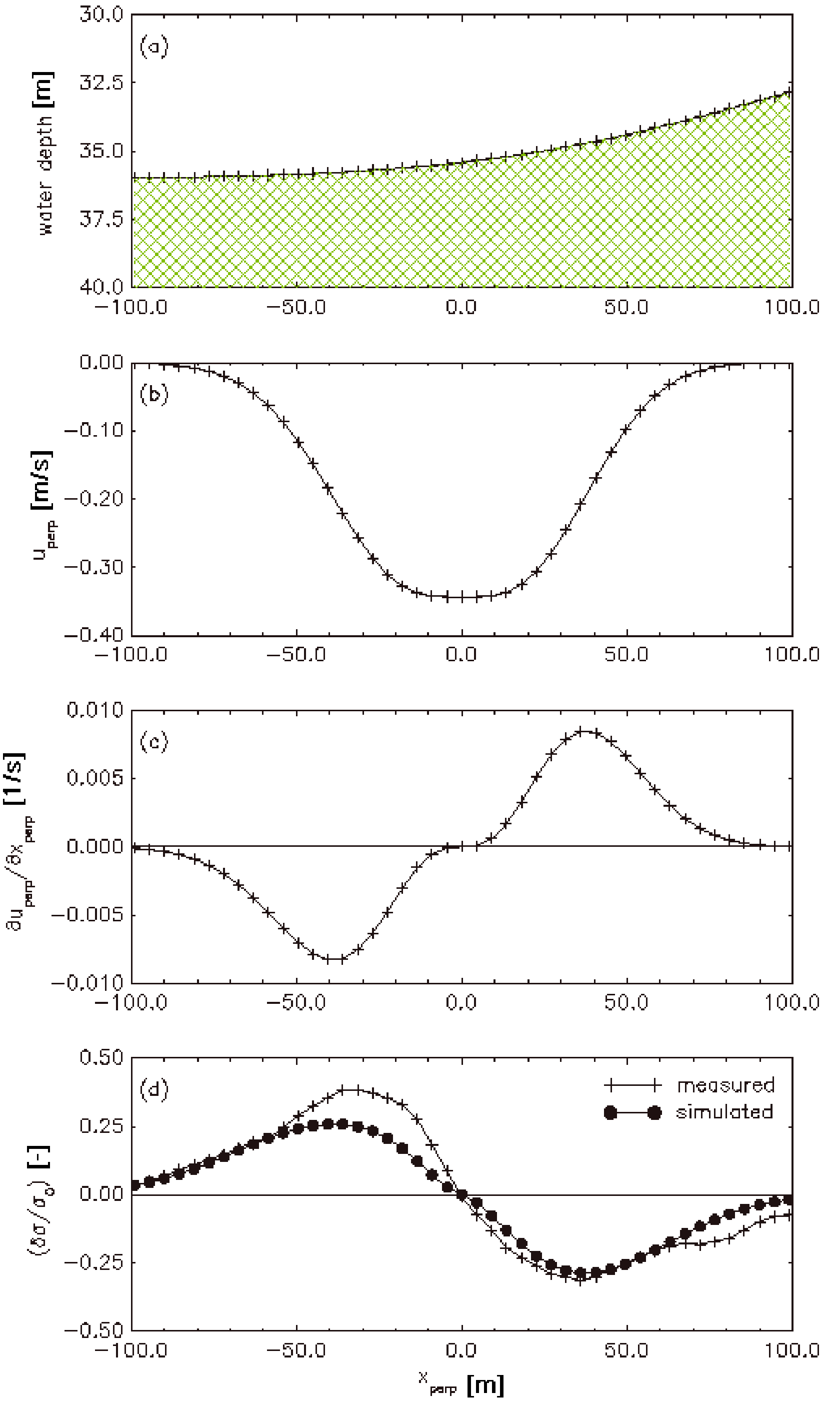

Figure 2: Results of simulations according to Hennings and Herbers (2010); (a) water depth as a function of x_{perp}, (b) perpendicular current speed $u_{perp} = u^*$ relative to the unidirectional tidal current flow U_0, (c) strain rate or gradient of the perpendicular component relative to U_0 of the current velocity $\partial u_{perp}/\partial x_{perp}$, (d) comparison of simulated $(\delta\sigma/\sigma_0)_{sim}$ and measured $(\delta\sigma/\sigma_0)_{meas}$ NRCS modulation.

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BIOGRAPHICAL NOTES

Ingo Hennings was born in Veerssen (Uelzen), Germany, on 30 May 1952. He received the diploma degree in oceanography from the University of Hamburg, Germany, in 1984, and the Ph.D. degree in physics/electrical engineering from the University of Bremen, Germany, in 1988. From 1968 to 1978, he sailed on board of ocean-going merchant vessels and is holder of the German ship captain's certificate foreign trade master (AG). From 1985 to 1988, he worked in marine remote sensing at the GKSS Research Center in Geesthacht, Germany. Since 1989, he has been a Research Scientist at the Leibniz Institute of Marine Sciences (IFM-GEOMAR) at the University of Kiel, Germany. His research interests include marine remote sensing with imaging radar and optical sensors as well as sea bottom topography current wave interaction.

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