Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2012, 32(104) z. 1 pp. 26–28

2012, 32(104) z. 1 s. 26–28

Detection of the sea surface currents by two-polarization X-band radar IKI-2

Yu.A. Kravtsov[1], M.D. Raev[2], E.I. Skvortsov[2]

[1] Maritime University of Szczecin, Faculty of Mechanical Engineering, Department of Physics
70-500 Szczecin, ul. Wały Chrobrego 1–2, e-mail: y.kravtsov@am.szczecin.pl
[2] Space-Research Institute
Moscow, Russia, e-mail: mrear@rssi.ili.ru

Key words: observation method, radar signals, accuracy

Abstract

New two-stage method for observation and processing of radar signals and images is suggested, which uses two-polarization X-band radar and significantly improve accuracy of sea surface current velocity measurement.

Introduction

Studies of the sea surface and surface currents by radar methods were provided in last 30 year.

Advantage of X-band radar is their low cost. Such radar allows convenient observation of large aquatories with sufficiently good spatial resolution. Range of X-band radar achieves 5 km. Under pulse duration of 60–80 ns radar resolution in distance is up to 8 m, and azimuthal resolution might be 0.8–1.0º.

Determination of velocity and direction of surface currents by short-wave radar is performed on the basis of standard algorithms, using spectral processing of radar data, obtained in scanning regime. Current velocity is calculated then on the basis of dispersion relations for surface gravitation wave for deep water:

$$\omega = \sqrt{gk} + ku\cos\alpha \qquad (1)$$

where: ω is frequency, k – ware number, $g = 9.8$ m/s^2, u – current velocity and α is angle between direction of seeing and current velocity.

In fact, revealing of gravitational see wares from observation, obtained by standard navigational radar with horizontal polarization is deteriorated in presence of speckle-like signals, caused by non--Bragg mechanism of electromagnetic ware scattering, characteristic for grazing angle observations at horizontal polarization. Influence of this scattering is important for low wind velocity and gravitational waves height less than 1 m.

By the way of example, figure 1a presents radar image at horizontal polarization (h-h images) under low wind velocity 3–4 m/s. Figure 1b shows corresponding temporal-spatial spectrum.

a) b)

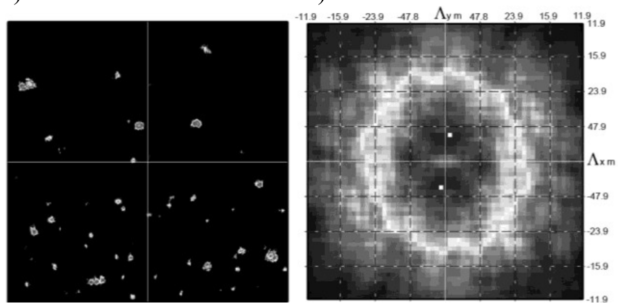

Fig. 1. Radar image at horizontal polarization (a) and corresponding temporal-spatial spectrum (b)

Unfortunately, reveling of the sea current parameters from similar h-h radar images with acceptable accuracy is not achievable. That is why vertical polarization is preferable as compared to horizontal one.

New method of observation one processing

Measurements accuracy of sea surface current velocity can be significantly improved by using, first, vertical polarization instead of horizontal one.

Secondly, in distraction to traditional navigational radar, our method implies longer time for signal accumulation.

The first results, obtained at vertical polarization, are presented at figure 2a for v-v polarization. This radar image radically differs from h-h image at figure 1a. Corresponding temporal-spatial spectrum, shown at figure 2b, also is much more informative than spectrum at figure 1b.

a) b)

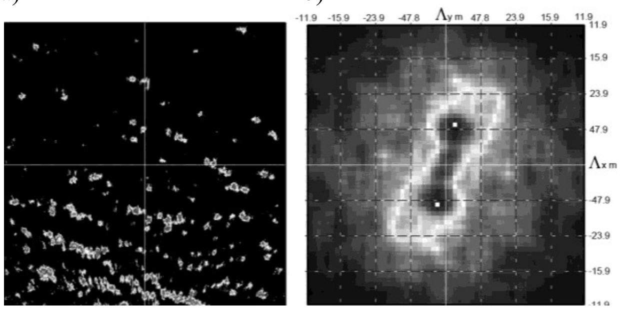

Fig. 2. Radar image at vertical polarization (a) and corresponding temporal-spatial spectrum (b)

Measurement with longer time of accumulation was performed in two stages. At the first stage observation was provided first at vertical, and then at horizontal polarization. At first stage direction of dominating wind waves was determined.

At second stage observations were performed with unmovable antenna, fixed in direction of dominating wind wave.

Radar images were obtained with observation time 1 min and longer, whereas spectral analysis took 300–600 s.

Velocity of the surface current was determined from frequency shift at dispersion curve.

Radar IKI 1-2, implemented in our observations, has the following parameters:

1) working frequency 9800 MHz;
2) pulse-power 7.5 kW;
3) pulse duration 50 ns;
4) angular resolution 1º;
5) polarizations – vertical and horizontal;
6) angular velocity of antenna rotation 30 min^{-1};
7) radar was supplied with 16 bit Analog-digital converter (ADC) with frequency 100 MHz;
8) software was implanted, allowing continuous signal recording and processing both in circular scanning regime, and in regime of fixed antenna azimuth allowing accumulating signal.

Results of observations

Measurements of surface currents velocity were performed in the Blue Bay, Gelendzik on the Black Sea in 2010–2011.

Due to local topographic conditions (high rock at West shore of the Blue Bay) sector of observation was limited from 140º to 240º (from South-West to South East).

Wind waves propagated usual by along wind velocity. Wind velocity was typically 2–16 m/s. Time-periods were selected with wind being stable during 3–4 hours.

Typically surface current velocity is a sum of drift velocity (about 2.5% of wind velocity) and velocity of wave transfer about 8–10 cm/s.

It was taken into account that drift velocity declines at 45^{o} to the West (Eckman's shift) from wind velocity. Figures 3 and 4 present temporal-spatial spectra at vertical and horizontal polarizations for fixed antenna to the some weather conditions, characteristic for figures 1b and 2b: wind velocity about 3–4 m/s.

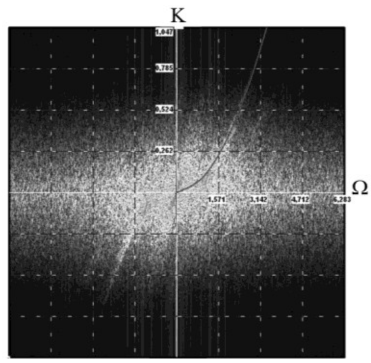

Fig. 3. Temporal-spatial spectrum at vertical polarizations for fixed antenna

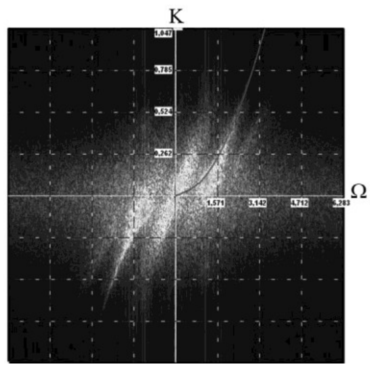

Fig. 4. Temporal-spatial spectrum at horizontal polarizations for fixed antenna

Current velocity measurements at horizontal polarization were not effective, as was explained before. Such measurements are much easier to perform at vertical polarization.

In a given case current velocities, determined from there subsequent images, were 14.1, 14.6 and 13.8 cm/s. Under wind velocities larger 8–10 m/s differences in radar image texture at vertical and horizontal polarizations decrease, in spite of distinction in scattering mechanism: if at vertical polarization as a rule resonance mechanism of scattering dominates, at horizontal polarization the non-resonant scattering prevails, which is caused by small-scale steep waves which are undergone to breaking.

At horizontal polarization oblique tracks at radar image are observed (Fig. 5a), which differ from tracks at vertical polarization (Fig. 6a) by shorter length and spatial modulation. Though temporal--spatial spectra, obtained at horizontal and vertical generally are similar to each other, images at vertical polarization have explicit advantages. Examples of these spectra obtained at wind speed 13–14 m/s are shown at figures 5b and 6b.

a) b)

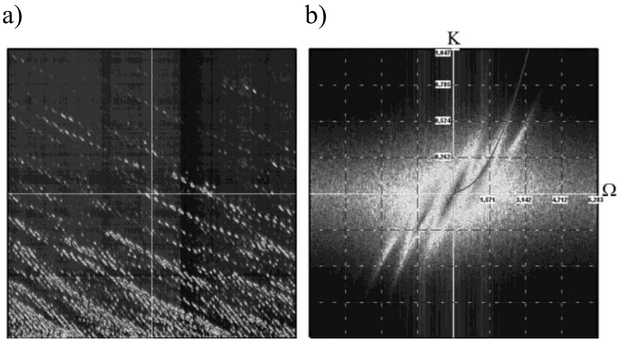

Fig. 5. Radar image texture at horizontal polarization (a) and temporal-spatial spectrum (b)

a) b)

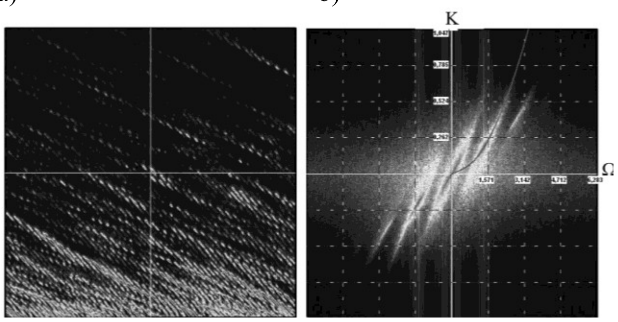

Fig. 6. Radar image texture at vertical polarization (a) and temporal-spatial spectrum (b)

Due to speckle nature of radar images, spectra at horizontal polarization are more diffusive than at vertical polarization. Because of this current velocities, extracted from images at horizontal polarization are undergone to large spread that at vertical one.

Under viand velocities 12–13 m/s measurements the following values of current velocities were obtained: 26.1, 19.2, 32.9 and 32.6 cm/s at horizontal polarization, and 31.0, 32.9, 36.2 and 29.6 cm/s at vertical polarization.

Velocity of drift current estimated from synchronous measurements of the wind velocity was 39 cm/s.

Conclusion

In distinction to images obtained by traditional radar with horizontal polarization, our method, using predominantly radar with vertical polarization has unconditional advantages due to signal accumulating at fixed antenna position. This approach allows improving accuracy of current velocity measurements, and is able to study surface current at low and moderate wind velocities. The method under discussion is easy to realize and allows obtaining higher quality of the sea surface monitoring in coastal zone.

Acknowledgements

This work was carried out within the frame of the fundamental research of Russia Academy of Science of the problem "Radio-electronic methods in environment researches". Authors indebted to Dr. B. Bieg and I. Kochkodaeva for valuable assistance in manuscript preparation.

References

1. Young I.R., Rosenthal W., Ziemer F.: A three dimensional analysis of marine radar images for the determination of ocean waves directionality and surface currents. J. Geophys. Res. 90, 1985, 1049–1059.
2. Kravtsov Yu.A., Raev M.D., Skvortsov E.I.: Manifestations of the resonant (Bragg) and non-resonant mechanisms of scattering on radar images of the sea surface. Internet Radar Symposium'09, Hamburg, September 9–11, 2009.
3. Wu J.: Wind-Induced Drift Current. J. Fluid Mech. 68, 1975, 49–52.
4. Ekman V.W.: On the influence of the earth's rotation on ocean currents. Ark. Mat. Astron. Fys. 2, 1995, 1–52.