Further Modification Practical Method for Estimating Directional Wave Spectrum by HF Radar

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ABSTRACT
A new modification in a practical method for directional spectrum parameters by HF radar is presented. This new method is a further modification of Bayesian method reported by Hashimoto and Tokuda (1998). In this paper, a formulation of directional spectrum is characterized by an exponential function having the power expressed by a Fourier series over the directional range and assumed to be a piecewise-constant function over the frequency range. The applicability and accuracy of the proposed method are comprehensively examined using numerical simulation and field data of various wave conditions. The results suggest that modified method provides several advantages more powerful, potentially more accurate and faster solution techniques in practical method.

KEY WORDS: HF radar; directional wave spectrum; spectrum; wave observation; wave data analysis; currents measurement; Bayesian method.

INTRODUCTION
High frequency radar is a very useful tool to measure ocean surface current with real time observation, also for wave spectra and wind direction. The simultaneously observational technology for sea surface currents by HF radar sea-echo Doppler spectrum has already been established and applied into practical use. Nonetheless, the estimation of directional wave spectra remains unexplored, and limited to theoretical aspect the greatest barrier is to accurately estimate the Doppler spectra.

Several methods have been developed to estimate directional wave spectrum (Lipa and Barick, 1986; Wyatt, 1990; Howell and Walsh, 1993; and Hisaki, 1996), with some advantages and limitations. Nevertheless, the majority of them are yet unable to reflect the practicality of the method. Wyatt (1990) employed Chahine-Twomey algorithm to estimate directional spectrum with efficient computational method, and already well established in Europe. A different approach was introduced by Hisaki (1996), who proposed a method to estimate directional wave spectra using HF radar and solve the nonlinear integral equation iteratively with additional conditions. He introduced a priori condition where the directional wave spectrum is assumed to be a smooth and continuous function. In addition, he also introduced other conditions that the directional wave spectrum has a value greater than zero, and it changes according to the known ratio in both frequency and directional angle. These cause the prior conditions to be in excess of the number of unknown parameters, within fundamental equations. However, the issue of setting the empirical weighting coefficients imposed on each of the additional conditions was still remained.

The great efforts have been made by Hashimoto (1997) to introduce the basic concept of Bayesian approach in estimating directional wave spectra from HF backscattered information, which was initially designed in 1986 as part of the Comprehensive Multi-Quantity Directional Wave Measurement Project of PARI Japan. He described details of mathematical theory of Bayesian method to analyze second order component. The use of Bayesian method had a significant progress for various wave conditions. However, noise-contamination of the measured Doppler spectra which is significantly distorted from the theoretical one (Hashimoto and Tokuda, 1998) are still problematic, eventhrough this method was one of the most accurate and reliable methods, provided good accuracy and more powerful. Furthermore, Hashimoto et.al (2003) verified the Bayesian method with the directional spectrum obtained from directional buoy. The Bayesian method is examined and compared with Wyatt method using SCAWVEX (Surface Current and Wave Variability Experiments) and EuroROSE (European Radar Ocean Sensing) from in situ measurements. Detail comparisons were excellently presented and confirmed that the Bayesian method is showing more robust than the Wyatt method, despite the fact that the drawback of the Bayesian method required more time consuming computation and to some extent was not yet practical.

In order to overcome the disadvantages and retain the advantages of Bayesian method, a new theoretical approach is proposed. The theoretical approach is modified using MEP (Maximum Entropy Principle) developed by Hashimoto and Kobune (1986). This modification significantly improved the directional wave spectra estimation in practical use. Details of modification and outputs are...