The Big Data Processing of HF Sky-Wave Radar Sea Echo for Detection of Sea Moving Targets

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ABSTRACT
A high-frequency (HF) sky-wave radar always monitoring large area of sea surface, for detecting sea surface moving objects, there must be big data waiting to be processed. A set of data processing methods were proposed, the successful implementation of HF sky-wave radar on the sea moving target detection. By setting the HF sky-wave radar parameters, after the initial data processing, the gotten HF sky-wave radar data were saved. Then a new HF sky-wave radar data processing method was provided, this method was the so-called three-step detection method (TSTM) which based on the constant false alarm rate (CFAR) technique. By using TSTM, setting the decision threshold G, with false alarms being ruled out, a moving target was detected out at last, its speed was calculated. The results also proved that TSTM could effectively reduce the sea clutter, and greatly lessen the echo-broadening and double-image caused by ionosphere contamination.

KEYWORDS
Big Data, Detection Threshold, HF Sky-Wave Radar, Range-Gate, Target Detection

1. INTRODUCTION
High frequency (HF) sky-wave radar emits pulse waves which have good coherence, stable frequency and phases. When the waves reflect from sea surface, the echoes contain Doppler frequencies (Hua & Meng, 2007; Bo & Hu, 2015). By analyzing the Doppler echoes power spectra, moving targets signals could be detected (Lee & Choi, 2014; Li & Yang, 2014).

Ship speed is much slower than that of airplane, in the Doppler power spectrum, the ship Doppler peak is usually near the Bragg peak or the much more powerful sea clutter (Sun & Qi, 2005; Cheney & Bordenz, 2008); most of the intervals, high frequencies (3-30MHz) were intensively exploited to bring to radio frequency (RF) interference (Pan & Wen, 2013); HF waves propagation used to be subject to the transient interference of atmospheric noises and lightning besides ionosphere disturb (Ignatenko & Tinin, 2003; Mao & Hong, 2015); and both of the range and azimuth resolutions of HF sky-wave radar are particularly much worse; In addition, an HF sky-wave radar usually supervises vast area, big data need to be dealt with.

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HF sky-wave radar’s target detection is by using the ionospheric reflection, and the ionospheric is randomly changing and unstable due to solar radiation (Barucci & Macaluso, 2010), space ions and other effects; and so unstable is the ionospheric transmission characteristics in different seasons, day and night; the unstable has many effects on the transmitted signal. The homogeneity in the ionosphere makes the clutter and target echo have different random translations on the distance and Doppler frequency, and with the additive mixing, the “ghosting” appears, which results in stretching and splitting of the spectral. When the radio waves through the ionosphere, the wave phase will also change, the ionosphere effect on the wave is called phase perturbation. This phase modulation may be linear or non-linear in the coherent accumulation time, the linear phase perturbation is a frequency translation of the radar echo spectrum, which resulting in the error of the target velocity information; while the non-linear phase perturbation could lead to the expansion of the clutter region, radar echo Doppler spectrum shift and widening. Both the phase disturbance and the ionospheric inhomogeneity can lead to the enlargement of the clutter region and the generation of ghosting clutter, cause the radar echo spectrum broadening, all of which will seriously affect the detection ability of slow target (Anderson & Abramovich, 1998).

All of the above indicate the target detection with sky-wave radar is a very hard job.

The rest of this paper is organized as follows. Numerical simulation of HF radar sea echo Doppler spectrum and its comparison to measured data is set forth as section 2. In section 3, we introduce HF Sky-wave radar system and its signal processing flow, the introduction of the data pre-processing was also included in this part. In section 4, we provide the three steps test method which based on the constant false alarm rate technique. Then the TSTM being applied to the gotten data for target detection is followed as section 5. The last section discusses our current and future work.

2. SIMULATION OF HF RADAR SEA ECHO DOPPLER SPECTRUM

2.1. HF Radar Sea Echo Doppler Spectrum

Barrick used the boundary perturbation method to quantitatively explain the formation mechanism of the first and second order echoes of narrow beam HF radar on random sea surface. Assuming no ocean surface flow, the derived first-order (Benjamin, 1998), second-order HF radar section equations by Barrick were (Barrick, D. E., 1972; Lipa & Barrick, 1986)

$$\sigma_1(\omega, \phi) = 2^a \pi k_0^4 \sum_{m_i=\pm 1} S\left(-2m_i^2k_0^2\right) \delta(\omega - m'\omega_0)$$

(1)

$$\sigma_2(\omega, \phi) = 2^a \pi k_0^4 \sum_{m_i, m_i'= \pm 1} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} S(mk) S(m'k') \delta(\omega - m\sqrt{gk} - m'\sqrt{gk'}) dp dq$$

(2)

After the quantities in the radar cross-sectional equation being normalized, Equation (1) and (2) were simplified to the following dimensionless form (Lipa & Barrick, 1986):
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