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Study on Microwave Scattering Characteristics of Sea Water and Oil Spill Based on the Indoor Measuring Method

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Abstract

With the capabilities of all-weather, all-time and wide geography scope, microwave remote sensing has provided an effective monitoring technique for ocean oil spills. This paper analyzed the theoretical basis of oil spill microwave scattering and the existing oil spill scattering model. By using indoor microwave scattering measurement system, the scattering coefficients of the simulated sea water and oil spill under different conditions were measured choosing a reasonable number of independent samples to insure high measurement accuracy adopting the time-domain technology and metal plate calibration methods. The relation among scattering coefficients of sea water and oil spills, the parameters of the incident wave (including different polarization, incidence frequency and angle), the sea water parameters (different wind speed and direction) and the parameters of oil spills was studied. The scattering coefficient database and oil spill microwave scattering mechanism based on the simulation results will provide the theoretical basis for the design for sensors and analysis of remote sensing data on oil spill monitoring.

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Keywords: microwave remote sensing; back scattering coefficient; oil spill; sea water

1. Introduction

According to China MSA, there are more than 10900 vessels for coastal transportation and more than 2400 oceangoing ships in China. Net deadweight reaches 65 million tons. 90% of the 0.27 billion tons of imported crude oil transportation was through the sea in 2012. There were 151 oil spill accidents of over 10 tons caused by ships from 1973 to 2013 in the coastal areas of China. The 7.16 oil spill accident in Dalian and the 19-3 platform oil spill accident in Penglai posed more severe challenges to oil spill monitoring technology.

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With the capability of penetrability, all weather, day or night imaging, microwave remote sensing technology, which has been rapidly developed since 1960s, has been widely used in oil spill monitoring. But, the existing microwave remote sensing technology still has problems with detecting and accurately distinguishing oil spill or suspected oil spill. The solution to the problem must obtain the deeply research of dielectric property and microwave scattering property of oil spill, but only analyze the image grey scale information and radar image texture. To measure microwave scattering property of oil spill by indoor scattering measurement system forms the basis of target classification, recognition interpretation of remote sensing images. At present, despite a large amount of theoretical and experimental researches have been made at home and abroad, most of the studies were restricted to microwave radiation characteristics of typical crops and soil (JIA Mingquan, LU Haiping, CHEN Yan, TONG Ling, 2009).

The paper elaborated on the mechanism of microwave scattering measurement, and researched parameter inversion on oil spill by back scattering coefficient variations with established indoor scattering measurement system. It provided theory reference for microwave remote sensing monitoring on oil spill.

2. Theoretical Basis on Oil Spill Microwave Scattering Measurement

2.1. Theoretical basis of microwave scattering

Radar Equation. Radar equation is a mathematical expression that describes the relationship (ignore the atmosphere element, etc.) among the echo power received by radar antenna, radar system parameters, and target scattering characteristics. Providing that the wave transmitted by radar antenna is spherical wave surrounding the antenna, and the echo reflected by surface target is spherical wave surrounding the target, if the loss of the transmitting system, receiving system, transmitted wave, scattered wave, propagation process and polarization is ignored, then the echo power P_r received by the antenna should be expressed as:

$$P_r = \frac{P_t G_t}{4\pi R_t^{\,2}} \sigma_A \frac{1}{4\pi R_r^{\,2}} A_r \tag{1}$$

Among them, P_t is transmitting power, $A_r = G_r \lambda^2 / 4\pi$ is the effective area of the receiving antenna aperture, G_r and G_t are separately gains of transmitting and receiving antenna, λ is the length of transmitted wave, σ_A is the normalized radar back scattering cross section of the target receiving area, R_t and R_r are separately the distances from transmitting and receiving antenna to target.

From the reciprocal theory, transmitting and receiving gains are the same owing to their same antenna. The parameters (subscript t and r) of Eq. 1 will be the same in the case of back scattering. From the radar equation, it will be a direct correlation between the echo power and backscattering coefficient when the radar parameters P, G, λ and the distance from radar to target R are determined. The backscattering coefficient expresses on the radar image is the image gray level, which is the back scattering echo intensity of surface target and often is expressed by backscattering cross section σ or backscattering coefficient σ^0 .

Radar Cross Section. The scattering energy (called Back Scattering) of radar incident wave source forms the radar echo, where the echo intensity should be expressed by the Radar Cross Section (RCS) with σ .There are two forms of the RCS definitions:

(1)Definition based on electromagnetic scattering theory