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A Survey on Target Detection Techniques under Sea Clutter

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ABSTRACT: The Sea is having a lot of clutter scatters, radar echoes those are superimposed and it is exposure to electromagnetic signals generated by the sea, and it is affected by the wind, ocean currents, waves and other exhibits of non-uniform and non- stationary parameters, this will create an impact on radar target detection capability. This paper deals with the matter of survey about various papers talks on the subject of the distribution of sea clutter characteristics of the radar platform and target echo of the sea on three factors which affect the target detection capability under the sea clutter to sort out the analysis.

KEYWORDS: sea clutter; radar platform; target echo; target detection

I. INTRODUCTION

Since the advent of radar, target detection under the clutter has been one of the main challenges facing radar technology. Sea clutter and radar target detection under the radar issue has been a hot research field. Effect of radar detection capability at sea clutter involves three factors: the distribution of sea clutter characteristics; the impact on the detection of target properties; the impact of the detected radar platform.

Sea clutter is the radar signal irradiated to the surface of large quantities of scatters echo superimposed sea miscellaneous Pod describe the general characteristics of the statistical distribution of sea clutter distribution segment by electromagnetic waves , polarization, resolution, incidence angle , surface wind speed affecting ocean currents, surges , etc. , thus exhibiting a certain degree of complexity , heterogeneity and non-stationary , sea clutter along the sea echo in the target environment impact on radar target detection capability.

Radar platform motion vectors received electromagnetic wave irradiation, radar platforms, the size of the velocity of the impact of sea clutter Doppler distribution, leading to different effects on target detection in clutter. The sea is the main radar target echo signal detection, target velocity, RCS and other conditions also affect the size of the radar detection capability Factor. From the above three aspects of factors that affect the target detection capability under the sea clutter to sort out the analysis , pointed out that recent progress and trends in the field.

II. IN SEA CLUTTER CHARACTERISTICS OF TARGET DETECTION

The study parametric modelling from the beginning as a Rayleigh distribution , lognormal and other progressive development of multi-parameter K distribution , complex Gaussian distribution [1], etc. , but found in the practical application of these models It is not perfectly found the reason sea clutter generated is complex and diverse , the electromagnetic spectrum , resolution , polarization, angle of incidence , ocean currents , wind , tides, waves , etc., affect sea clutter , it presents irregularities in the spectrum, the magnitude of the statistical distribution of hard to describe with the formula . Sea clutter modelling single reflect the physical characteristics of sea clutter.

A. Resolution On The Impact Of Sea Clutter

With the development and application of high-resolution radar , sea surface target detection performance has been some improvement , but with the observed scattering points can be increased per unit area , the impact of sea clutter on target detection performance is becoming increasingly significant , range resolution cell becomes smaller , the statistical characteristics of sea clutter gradually deviated from the Gaussian distribution , and the " tail" is serious , the traditional method of performance testing is reduced.

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In the high-resolution radar echo, the increased resolution makes resolution cell size becomes smaller, the number of strong scattering point within the cell is reduced, and its scattering Heart description of the physical characteristics of the more detailed objectives, polarization scattering characteristics of the target reflects its structural features are also more detailed. Carlos L. [2] and other characteristics of the target transient polarization decomposition done a lot of research and practice, and target classification and identification were polarized decomposition and belong to Domestic side. Zhuang Zhao Wen, Wang Xuesong [3], who authored multiple books polarization feature extraction of polarization information in the promotion of applications, has made a significant contribution. Among them, Wang Xuesong establishes a new polarization information processing basic framework for polarization feature provides a theoretical basis for extraction.

B. Effect Of The Angle Of Incidence Of Sea Clutter

1) Small Incidence Angle Case

Radar to sea when a small incident angles , the radar echo intensity will be significantly enhanced, the probability density function curve amplitude noise will be significant smearing , namely sea peak effect [4] . Sea spikes serious impact on target detection capability, so that the false alarm rate becomes larger. In recent years, researchers have studied sea spikes indicates one of the sea as the sea clutter spike reflected a non- uniform characteristics, with strong fluctuation characteristics. [5] Found that the level of polarization and upwind of sea clutter phenomenon is more pronounced spikes in the sea. Gutnik VG noted that relations of spatial statistical characteristics of sea spikes surf and sea [6], by the angle of incidence and the sea a negative correlation between the shaded area is proposed sea shadow function for analysing sea spikes provide a quantitative description .Posner Fred L [7] by processing a large number of measured data obtained at low grazing angle, high-resolution and horizontal polarization sea more frequent conclusion spikes occur . Posner F. From the quantitative point of view gives a description of the three characteristic parameters sea spike [8]: sea peak amplitude threshold, the minimum sea peak width and minimum spacing between adjacent sea spikes , which can describe the statistical measure of the average sea spike duration and average peak spacing of adjacent sea . Luke Rosenberg [9] use time amplitude distribution obtained from the threshold to distinguish data Bragg scattering and sea spikes, found mainly in sea peak HH polarization of low grazing angle region, as well as a small part of the emergence of VV polarization in side wind section.

To study the properties of the sea by establishing spikes Model Literature [10] K distribution model, use the binomial distribution to count sea spikes frequency. C-band and the measured data are processed, draw good conclusions K distributed more than any other model fit, but with the improvement of the false alarm probability, binomial and Poisson distribution will tend to normal, but the actual sea spike statistical characteristics are not subject to the normal distribution. Thank Hun Sen [11] gives a texture component extraction algorithm is proposed based on generalized K lognormal distribution model texture, measured by X -band data Verify that the model has a good fit. Bandiera Fetal, Ref [12] studied using generalized likelihood extended target detection under Gaussian colored noise ratio detection technology, but because this method is only applicable to echo direction vector is known, it can only be applied in coherent radar system. Blunt SD et al. [13]. The binary detection distance of the window, and then Pulse ideas between binary detection, and achieved good detection performance, but on the parameter optimization could not give the detailed selection criteria. [14] studied the binary detector parameters and noise shape parameter, expansion of relations between the radial length of the target, given the parameters of the optimal binary detection empirical formula and selection criteria , simulation results confirm the usefulness and effectiveness of the optimal binary detector.

2) The High Incidence Angle Case

When the radar illumination angle of incidence of the sea beyond a certain angle, spectacular scattering effect of sea clutter increases, the rapid rise in unit scattering coefficient , although Irradiated surface of sea clutter becomes smaller, but rapidly rising sea clutter scattering intensity . Target detection requires strong against sea clutter, and because the radar photo shoot sea footprint smaller, less clutter radar echo of independent units , the number of reference cells can be used to estimate the parameters of the clutter is reduced, the estimation error increases, not even enough noise parameter estimation unit common cause clutter CFAR detection algorithms fail .

When the radar towards the sea beneath the surface irradiated positive, on the basis of strict tests, it was found that the angle of the cross-sectional area of sea clutter is almost independent of frequency [15]. It corresponds to zero when there is a maximum wind speed of about + 15dB, and a negative correlation with the wind speed links. Large grazing angle scattering is generally considered with dumping an inclined surface specular scattering. When, the radar with a

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large incidence angle illumination, the sea will produce the phenomenon of broken waves, and generation of multi-target effects on multiple successive distance units, reducing the detection performance of radar targets. Scholars using different means of sea under large incidence angle simulated and processing.
DSW Kwoh, [16] found that the wave grazing incidence (LGA) under prone to broken phenomenon , proposed to split scattering approximation , and based on perturbation method and GTD gives the tension fluctuation scattering component and scattering component analytical hack . Some academics have also aligned spectacular scattering region was studied [17] The analytical formula quasi spectacular scattering region sea surface scattering coefficient and made vertical antenna beam incident on the sea surface scattering coefficient correction method . [18] Summarizes the different sea conditions, sea level changes of the mirror different polarization, different azimuth and angle of incidence of the case , the use of Gram-Charlier distribution Obtained after sea surface specular scattering cross section to quantitative analytical formula .

Correction for research and scattering coefficient also achieved good results. Huang Ji-ying et al [19] were evaluated using perturbation theory and method of calculation the average set of small-scale and large-scale roughness of the backscattering coefficient, and proposed substituting Weibull slope with a large -scale two-scale model of the next incident angle greater than 60 degrees Come on backscattering coefficient for correcting the thinking coupled with a computer method for Gaussian distribution and incidence angle greater than 80 degrees. [20] were used VRT (Vector Radiative Transfer Equation) and TSM scattering coefficient equations and sea foam layer , and after a white canopy cover weighting factor to obtain the total scattering coefficient .
[21] For moderate and high incidence angle shadowing effect quantitative analysis , shadowing effects will be with the angle of incidence , the rough surface and root mean square slope Scattering angle increases and more obvious, and the introduction of Kirchhoff approximation formula obtained scattering plane. Some scholars on two-scale model has been improved to make it more precise fit the measured data, such as Wang Yunhua et al. [22] two-scale model uses improved spectral characteristics of the scattered field into the sea Bank analysis found that grazing under the shadowing effect increases the frequency shift of the scattered field, shorten the spectral width of the phenomenon.

3) Sea Clutter Nonlinear Modeling Problems

With the development of signal processing technology, some of the new technologies used in the analysis of sea clutter, such as multi-fractal analysis, chaos model, artificial neural network and wavelet analysis. Simon Haykin, etc. through a large number of sea clutter data analysis method using correlation dimension made of sea clutter with chaotic dynamics. 97 years, Simon Haykin computing sea clutter Lyapunov spectrum and sea echo correlation dimension, discovery and correlation dimension spectrum similar Lyapunov dimension, and further study speculated that the sea clutter is 5 to 6 constitute nonlinear differential equations nonlinear dynamical systems. Morrison [23] was first proposed in 1993 to an estimated sea clutter fractal dimension using fractal method. 2002 Kantelhardt proposed multiracial Detrended Fluctuation analysis (MF-DFA) [24] method, may reflect more than one scalar index of singular measure, and effectively check the availability of a non-stationary sequence of multi-fractal characteristics. Common prediction neural network has BP neural networks, support vector machines (SVM) and radial basis function (RBF). RBF neural network has good nonlinear approximation ability, the ability to effectively improve the generalization problem of poor BP method, and SVM is based on the structural risk minimization principle and machine learning algorithms developed VC dimension theory, there is no generalization capacity. RBF neural networks and support vector machines with a good nonlinear predictive capacity has been more widely used in the detection of surface targets.

C. In Target Detection Radar Platform

1) Shore -Based Radar Platform

Shore-based radar and more in the islands, coastal mountains and other places, sea clutter shore-based radar observations is relatively simple. In shore-based radar system design, there are some possible ways to improve the detection performance of shore-based radars. Reference [25] describes the shore-based radar target detection should pay attention to the factors, and reduce clutter RCS weaken clutter propose ways: as reducing the azimuth beamwidth antenna diameter increases, widening the transmitted pulse bandwidth use between scanning the accumulation of sea clutter decorrelation distance, undulating performance improvement targets. Taking into account the waveguide effect [26] across the radar's impact should also be taken to reduce shore-based radar antenna side lobe level, increase the

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radar antenna height, increase the dynamic of the receiver and improve signal processing systems and other measures to improve improvement factor shore low-altitude radar detection capability. The study found that under the sea clutter radar unit the greater the resolution, the better the target detection capability, so broadband signal detection can be a good target detection capability enhancement under sea clutter. But broadband radar signal detection data rate cannot be real-time processing. Based on this, Chen Xixin proposed a secondary threshold noncoherent [27] detection scheme, to a reduction in the wideband radar data rate effects.

Between moving target detection (MTD) and pulse frequency agility radar clutter suppression and anti principal means active. But the emergence of new applications in real Problems between pulse frequency agility makes the scanning pulse between fluctuating target becomes the target, causing SNR ratio between adjacent pulses serious ups and downs. [28] Proposed an improved algorithm, in the back on the same Doppler frequency processing, non- coherent integration of different frequencies echo, simulation experiments show that this method improves the echo signal to noise ratio and improved target detection performance.

Ji Zhen Yuan [29] and other data processing obtained by the measured sea clutter spectrum analysis under shore-based observations verified frequency electromagnetic waves and waves will form a first-order effect analysis of two first-order Bragg peak in the Doppler spectrum. Wang Fuyou [30] and put forward the use of Hurst exponent difference in the physical characteristics of sea clutter estimate method , the measured data through data discovery from the door containing small targets with long-range dependence , Hurst difference as to verify the existence of this standard to judge whether the target effective place.
Ref. [31] From the perspective of both the vision and close-range ship detection shore platforms were described using OTSU algorithm and Hough transform and the projection method to detect vision, using a three- frame difference and background subtraction algorithm combines ease object texture structure frame difference after the " empty " and " double image " phenomenon, for close-range target detection, test results show that both strategies have a very high accuracy.
Airborne radar there is a certain speed, the use of a wide beam. The airborne radar on how to improve the ability to detect small reflection cross-sectional area of the track is the key goal of improving its performance. The key technology research mainly design optimum waveform, clutter suppression technology, object detection technology.
Airborne radar pulse Doppler system to use more common chirp waveform has burst signal, constant carrier frequency signal and the phase encoded signals. Linear FM signal advantage is echo Doppler shift is not sensitive to the disadvantage of the presence of coupling from the Doppler phenomenon, constant carrier frequency signal compared to the speed and distance with high resolution, but there is periodic speed, distance blur phenomenon. Phase- coded signals can simultaneously measure the distance and the Doppler frequency, but Because of its Doppler sensitivity, suitable for high-speed targets.

2) Clutter Suppression

Huang Yong put forward based on FFT frequency domain clutter treatment method [32], the MTD technology and AMTI technology combine the use of the frequency domain adaptive filter to achieve the purpose of the time-domain noise suppression the method of calculating speed and can effectively prevent target whitening. Zhong Ling [33] between the accumulation and use of scan logic phenomenon of false alarms under airborne platforms will be improved target detection.
The 1960s, the phase centre antenna (DPCA) [34] technology is used in motion compensation and noise suppression, the advantage is easy to implement, and can inhibit the good Lord clutter. Ref [35] The use of the pre- filter compensation carrier aircraft movement error, adaptive DPCA compensating amplitude and phase error. Dual proposed robust adaptive DPCA clutter suppression methods. Adaptive processing concept put forward 73 years from empty space-time dimension angle mention clutter suppression for a new idea. Xiao Yang et al. [36] According to the clutter covariance matrix and vector different goal-oriented model to establish the power spectrum, use STAP to analyse different characteristic spectrum PRF clutter, get STAP more suitable for high pulse repetition frequency. Eli Yadin proposed antenna main lobe clutter cancellation technology [37], in an echo using two identical sub-aperture antenna, first use a weighted DFT filter out clutter deep outside the pass band, depending on the platform after Open-loop adjustment parameter weighting coefficients, forming clutter airspace filtered pass band zero, the test proved that the method can improve the detection performance of clutter suppression.

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In target detection technology Laura Santos Ugarte [38] proposed the use of physical shielding, high antenna gain, side lobe cancellation and adaptive filtering Technologies to achieve direct coupling signal path of repression and to obtain a larger target echo peak. When airborne radar to detect surface ships, generally makes Non- coherent integration method or a single pulse, and by way of data processing to obtain the target speed projection filter tracking algorithm (PFLRR) [39] makes use of airborne radar moving target when dealing with a very good detection effect.

3) Onboard Radar Platform

Onboard radar platform because of its very high velocity, sea clutter Doppler usually ambiguous. In coherent radar system, the sea clutter due to the Doppler effects from the non-uniform distribution in the plane Doppler presented, many studies for missile-borne radar modelling undertaken: literature [40] radar search function simulation, within a certain range, the model reduces the complexity of the simulation, but because of its not fully reflect the radar signal processing, and therefore it cannot be applied to dynamic simulation. Liu Jian-cheng [41], such as design of the Doppler radar signal acceptance model and signal processing models, but ignores the target with a high-resolution radar and radar signal processing features in the case of relatively high speed. Ching T L. et al [42] analysed the shape of the beam angle, proposed phased array radar recess formed in the direction of interference to reduce the interference signal gain approach. Professor Fu Jiang studied the classification target manoeuvring characteristics, the use of quantitative targets marked acceleration sequence, based on the establishment of a first-order Markov (Markov) classifier [43] methods to identify the target acceleration sequence, the results show that this method has good recognition rate, and easy to calculate.

In addition to the onboard radar modelling, but it is also the use of side lobe suppression methods to improve detection performance. Richard K .[44] The pulsed Doppler technology and phased array technologies, adaptive signal processing side lobe suppression by the weighting of each element when the signal amplitude and empty. Wang Jianming et al [45] presented the main lobe interference suppression method based on blind source separation. Zhao Lei et al. [46] proposed the establishment of missile-borne radar -STAP model based on low-rank matrix restoration theory, the use of technology RPCA target sparse matrix isolated from the Doppler sequence. Ref. [47] proposed sequential detection algorithm Changing Scale Discrete Chirp-Fourier (B-DCFT) Transformation for acceleration detection targets. By measured data proved that correcting phased array radar spatial filtering algorithm and compensation IQ channel phase, respectively, can be a good side lobe suppression of clutter and the main lobe mirror frequency interference.

In signal processing, there are some good researches. Ref [48] The use of polarized and Doppler processing methods for speed and angle deception jamming to filter out. Ref [49] The use of the Doppler frequency distribution method to convert azimuth frequency distribution, isometric , and so the clutter Doppler line dividing grid, can be very good ease radial velocity caused by the Doppler shift phenomenon. Liu et al [50] introduced the stochastic resonance principle PD radar detection you can get a good SNR. Su Jin et al [51] proposed to distinguish multiple moving targets within the beam algorithm, using super-resolution spectral estimation to the slope of the Doppler spectrum back after treatment, so as to isolate single and multiple targets.

In addition, [52] proposed missile-borne radar polarization PD polarization filtering method using transient polarization conversion, polarization valuation high resolution signal from the pulse pressure after treatment, with the goal of suppressing good the same angle the interference signal from the unit.

D. In Target Characteristics Of Radar Detection

RCS target characteristic is mainly reflected in the size, velocity and other factors. In recent years, with the development of stealth technology, RCS reduction target control technology, making the ship detection increasingly difficult under the sea clutter, which itself is weak signal detection under a noise problem. Besides the high-speed moving targets easily lead to dramatic changes in the phase of the echo signal, the down signal accumulation efficiency, may also because signal becomes weaker. Another noteworthy problem is the slow movement of small target because of its sea clutter Doppler spectrum is located in the main lobe region, SNR is very low, and how to find the sea clutter or slow-moving boat stealth boat, divers and other slow even small targets under sea clutter is a challenge faced by target detection.

Its radial distance change rate change will produce higher powers. The study of high-speed moving target characteristics of this class is the key to improve target detection performance. Subcontracting network frequency shift algorithm through envelope alignment error compensation to improve the cumulative effect. Weak target detection

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algorithm and extended target detection method multiple pulses in Keystone transformation based on the phenomenon of walking distance unit to be amended.
Spectrum shifting error and echo signal processing method and RAT linear mixing parameter method can be a good measure of spectral bandwidth, and move to solve the error prone problem. In target tracking , literature [53] using an adaptive multi- track initiation algorithm assumptions gates and track initiation hierarchical method for quantitative analysis of track initiation , the literature [54] compared the product type ambiguity function (PHAF) and joint time-frequency representation both motion compensation methods and Application conditions of the two methods were divided .

In radar waveform also has some new progress. In Ref [55] the minimum mean square error estimation (MMSE) criterion adaptive waveform to improve recognition performance. Bin [56] gives guidelines under several different cognitive adaptive radar waveform design algorithm. Reference [57] by designing adaptive wave of Networking shaped radar transmitter waveform agility.
Because sea clutter correlation cannot lead to the accumulation of energy, so the slow small target detection first consideration to the relevant background. There have been some detection methods to detect between tracking and scanning before accumulated mainly in this context. Rutten M G. will repeatedly sweep the surface has been stored in the data processing Speed away from the two-dimensional image, the sweep surface data frames along a predetermined trajectory and the associated cumulative process [58], the use of inter- clutter energy and energy -related goals Difference, effectively removing background clutter, the disadvantage is the need to get in a multi-frame image in the target track, a very large amount of calculation. There are now a variety of improved methods, such as dynamic programming method. The fractal dimension of the key and put forward an inter-scan accumulated estimation method [59] of the traditional type parameter method was improved. Ref. [60] The variable step least squares (FB-VSLMS) algorithm for fractal parameter estimation, and on the actual results achieved a high detection precision Degrees and other detection methods using the modified Morlet distribution [61] were processed sea clutter data including target and non- target , increased by about 3dB detection performance.

III. CONCLUSION

From the existing research point of view, sea clutter signal processing mostly Use Sea clutter modelling, from the perspective of the statistical properties of the relevant line and the time and space to fit the measured data. Sea clutter nonlinear processing is a research direction in the future, with the improvement and development of chaos fractal theory will also promote the development of practical applications. Target polarization information may reflect the nature of its shape structure, can obtain more comprehensive information through the polarized target characteristic information. Polarization information processing and high-resolution technology has to be combined and have to achieve goal is to promote greater progress to identify a viable direction.

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