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Improved Techniques for Radar Clutter Minimization

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Abstract- ***Radar has got very much applications in the area of navigation and nowadays radars are installed even in small gunboats. Pulse Doppler radars are most frequently used radars in the current situation due to its efficiency in different climatic conditions and miscellaneous applications like Gunnery, surveillance, air-borne and, etc… But the main problem faced by a radar is its cluttering problem, ie's the presence of unwanted echoes in the received signal. The cluttering problem can be caused due to sea waves, mountains, rain and atmospheric turbulences. The fundamental parameter reflectivity (σ^0) is used to calculate the radar performance with respect to grazing angle, radar frequency, sea state and polarization. The implementation of the matched filter and controlling the amplitude response of the radar is simulated in this paper.***

Index Terms: ***Radar Clutter, Grazing angle, Radar frequency, Polarization and Matched filter.***

I. INTRODUCTION

The presence of radar clutter has affected the efficiency of the radar to some extent. Several research and experiments has been done to mitigate the cluttering problem in radar. Hence to study on the radar performance, radar reflectivity ***(σ^0)*** [1] constant is taken to analyze the spatial and temporal characteristic of radar. Matched Filter is an optimal linear filter used to maximize the signal to noise ratio. The K-distribution is a well advanced empirical model of radar sea clutters which is broadly used in radar performance calculations.

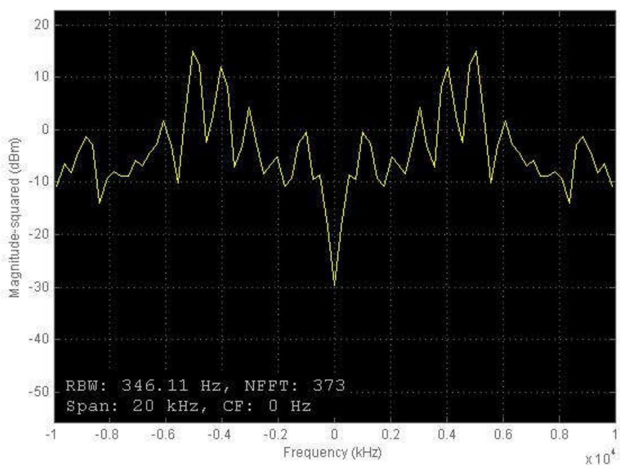

Figure 1: Received Clutter Signal of a Doppler radar

A. GIT, TSC and Hybrid Model

The basic characteristic of surface and volume clutter, as used in radar performance estimation, is its perceptible reflectivity defined as σ^0. The qualifier "perceptible" is used here as a reminder that any measurement of sea clutter reflectivity certainly includes the effects of shadowing and propagation close to the sea surface. Four parameters is included to evaluate the performance which are sea state (SS) according to the World Meteorological Organization (WMO), Polarization which the denotes the orientation of the transmitted and received wave, Grazing angle defined as the angle of incidence with respect to the sea state and Radar frequency which varies from (0.3GHz-35GHz).

Several models were implemented to minimize the sea cluttering problem. From that GIT, NRL, TSC and Hybrid models [2] were the efficient model. GIT model was introduced by the students of Georgia Institute of Technology. The GIT model explicitly allows for discretely specific inputs of average wave height and wind velocity for the effect of sea clutter reflectivity of rising and falling seas. Wave height is more commonly described in terms of the significant wave height defined as the average peak to trough height 1/3 of the highest waves.

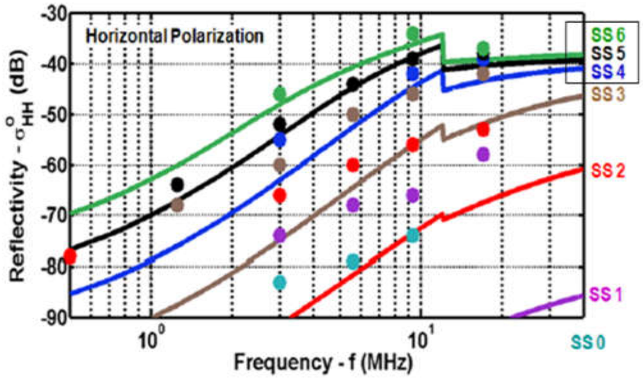

Figure 2: GIT Model Performance Graph

To develop the above figure, grazing angle is varied from 0.1 degree to 60 degree and radar frequency is varied from 0.35 GHz to 35GHz. The horizontal polarization is taken in to account for the experiment. From the figure, we can see that the model has poor performance at sea state 0, 1, 2 and 3. Rest of the sea state has an average value of reflectivity which indicates stable performance of the model at sea state 4, 5 and 6 [3]. The parameters of the sea state are added according to the World Meteorological Organization (WMO) codes.

WMO Sea State Code	Wave height	Characteristics
0	0 metres (0 ft)	Calm (glassy)
1	0 to 0.1 metres (0.00 to 0.33 ft)	Calm (rippled)
2	0.1 to 0.5 metres (3.9 in to 1 ft 7.7 in)	Smooth (wavelets)
3	0.5 to 1.25 metres (1 ft 8 in to 4 ft 1 in)	Slight
4	1.25 to 2.5 metres (4 ft 1 in to 8 ft 2 in)	Moderate
5	2.5 to 4 metres (8 ft 2 in to 13 ft 1 in)	Rough
6	4 to 6 metres (13 to 20 ft)	Very rough

Figure 3: WMO Sea State Code

Hybrid model is the combination of several clutter models and is introduced in an attempt to account for the possessions of the evaporation duct. The Hybrid model combines elements of the GIT model with new empirical equations.

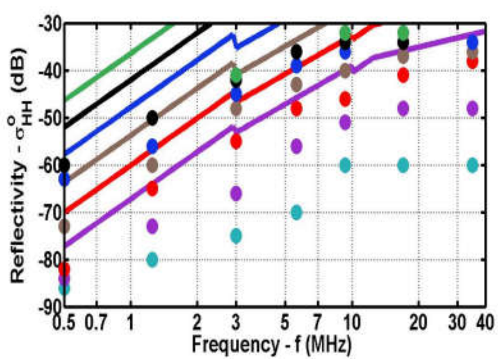

Figure 4: Hybrid Model Performance Graph

The variation in radar frequency has witnessed some problems in hybrid model. Hybrid model is most probably meant for stationary target detection. For moving target detection (MTI), all the sea state performed degradingly and reflectivity was not stabilized. Technology Service Corporation (TSC) is a commercial radar performance evaluation software package developed by Australian Defense Science and Technology Organization (DSTO). This model has resemblance with GIT model, but was not well recognized in MTI radar systems.

Figure 5 shows the performance graph of TSC model. We can see that for sea state 0, 1 and 2; the reflectivity with respect to vertical polarization has poor and unstable performance.

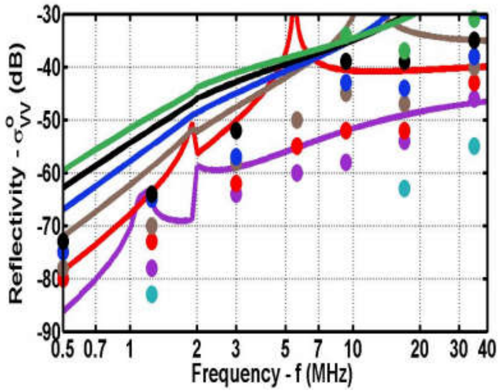

Figure 5: TSC Model Performance Graph

B. *Improved Model and Techniques for Radar Sea Clutter Minimization*

The point of departure for this paper is that any empirical model of sea clutter reflectivity, or any other sea clutter characteristic for that matter, must agree reasonably well with available experimental data [4]. The polarization values are taken using a Bridge Master E Series Radar. From the Nathanson's Model, and equation is derived by combining polarization, radar frequency, sea state and grazing angle [5].

$$\sigma_{H,V} = c_1 + c_2 \cdot \log_{10} \sin\alpha + \frac{(27.5+c_3\cdot\alpha)\cdot\log_{10} f}{(1+0.95\cdot\alpha)} + c_4 \cdot (1+SS)^{\frac{1}{2+0.085\cdot\alpha+0.033\cdot SS}} + c_5 \cdot \alpha^2 (dB)$$

Where, $\sigma_{H,V}$ is the reflectivity with respect to polarization; C_1, C_2, C_3, C_4 and C_5 are the constants used in this empirical model. α is denoted as grazing angle which is varied with radar frequency (f); SS is the sea state. The wind velocity is taken as 4 knots.

	POLARIZATION	
CONSTANTS	HORIZONTAL	VERTICAL
C1	-73.55	-49.57
C2	19.55	26.66
C3	7.36	0.700
C4	26.95	21.00
C5	0.00555	0.0022

Table 1: Constants Used in Improved Model

These values are given to the reflectivity equation. Wind velocity and wave height are taken as constants. Figure 6 shows the output of the horizontal polarized radar performance.

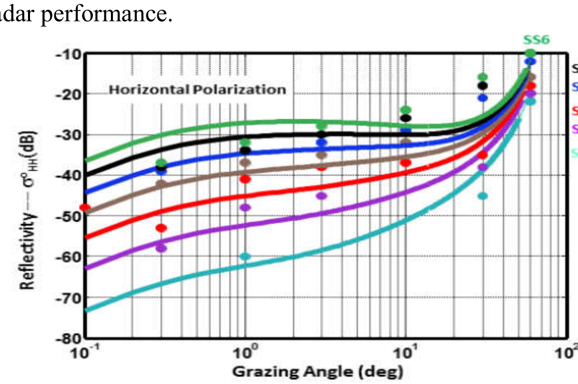

Figure 6: New Model Radar Performance (HP)

As we can see that all the sea state was seen in an average position of reflectivity indicating stable performance when compared with the other models.

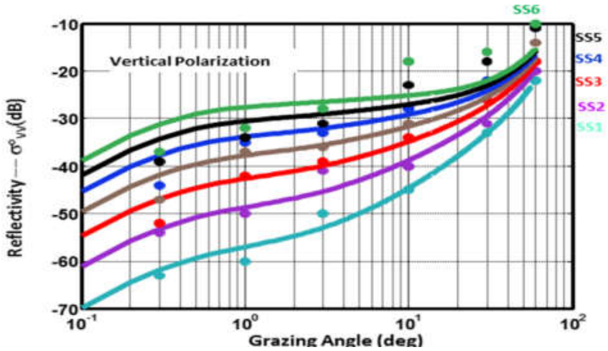

Figure 7: New Model Radar Performance (VP)

The vertical polarized reflectivity is simulated and output is given in Figure 7. As we can see that all the sea state was seen stabilizing at a particular reflectivity with varying grazing angle.

III. SIMULATION RESULTS

The design and development of empirical radar clutter model was implemented in MATLAB. The arrangement of the radar display was crafted like a Plan Position Indicator (PPI) with the concept that the target is moving in random direction [6]. The range of the radar is set to 120km and the clutters are randomly assigned using four quadrant inverse tangent. The absolute threshold of the system is assigned and can be varied. The intermediate frequency of the system is kept constant at 15 GHz.

The deviation of different models is taken from the performance graph. The vertical and horizontal polarization values are tabulated and are analyzed.

Model	Polarization	
	Horizontal	Vertical
GIT	13.3 dB	12.1dB
Hybrid	14.5 dB	8.7 dB
TSC	7.5 dB	10.5 dB
New Model	12.2 dB	12.2 dB

Table 2: Deviation of different Models

The table shows that deviation of the new proposed scheme has better deviation properties. The need for two antennas can be nullified using improved model. The deviation of the new model was seen almost null, indicating the efficiency of the improved model [7].

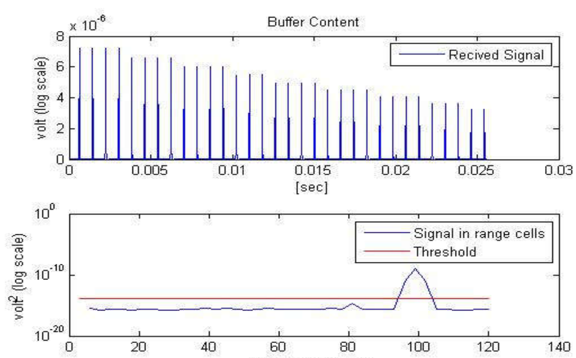

Figure 8: Buffer content and threshold (Without matched filter)

The above figure shows the received echo signal with respect to the amplitude and power of the received signal. Received echo will have less amplitude and power level due to interference and cluttering issues. The threshold of the transmitted signal is 10^{-14}. We can see that the threshold level was broken at 100km; hence concluding that the target was spotted at 100km from the antenna [8]. Figure 9 shows the received output of the echo signal with the implementation of matched filter. The threshold has leveled up; power and amplitude of the received signal was better when compared with Figure 8. Signal to noise ratio of the received signal maximized as peak of the signal which is denoted as interference or noise content is removed.

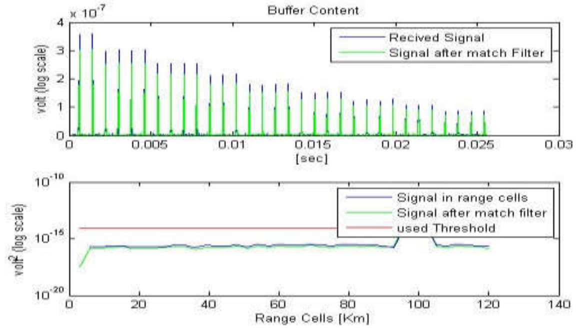

Figure 9: Received buffer content and threshold (With matched filter)

IV. CONCLUSION

Radar has been a vital device for the navigational and military purposes. The efficiency was a crucial factor in this domain. Hence to minimize this cluttering problem, different models were introduced. From the basis of these models, a new data based models was implemented. After the simulation, it was seen that for all the sea states; the reflectivity was seen on the better side. The deviation was nullified indicating efficiency. Using the Xerox of the transmitted signal, matched filter executes the maximum signal to noise ratio by clipping of the unwanted echoes with the referred transmitted signal.

V. ACKNOWLEDGMENT

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