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STUDY OF INFLUENCE OF THE ROUGH BOUNDARY ON RADAR REFLECTIVITY OF ISOTROPIC REFLECTOR

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Abstract- *The different models of the process have been attempted to calculate the propagation factor V. We propose a model of sea wave propagation and scattering for centimeter and decimeter waves for sea targets. The proposed model is based on a model for the radar reflectivity of the ship, taken as a set of localized backscatterers and on a four-path model of wave propagation above the sea expressions are obtained for the propagation factor dependence on the range of the ship, on the height of the radar antenna and on the sea surface roughness characteristics. Thus the key task in the considered problem is to calculate sea surface influence on radar reflectivity of isotropic reflector within grazing elevation angles.*

Keywords:- *Propagation factor, radar reflectivity isotropic reflector.*

1.1 INTRODUCTION:-

It is well known [1, 10, 9, 14] that measure quality in sea radio location is the product of radar cross section with the propagation factor of the sea surface (σV^4). In the line-of-sight (LOS) ranges the quantity $O \leq V^4 \leq 16$ [9, 10, 13], which makes it impossible to ignore the influence of the sea surface the propagation factor V depends on the range of the ship on the height of receiving-and-transmitting antenna on the sea roughness characteristics, and on some other factors. All known attempts to calculate V are based on different models of the process. Here we propose a model of sea wave propagation and scattering for centimeter and decimeter waves for sea targets. The proposed model is based on a model for the radar reflectivity of the ship, taken as a set of localized backscatters and on a four-path model of wave propagation above the sea. Expressions are obtained for the propagation factor dependence on the range of the ship on the height of the radar antenna, and on the sea surface roughness characteristic.

1.2 MATHEMATICAL CALCULATION OF INFLUENCE OF THE ROUGH BOUNDARY ON RADAR SCATTERING FROM ISOTROPIC REFLECTOR FOR GRAZING ELEVATION ANGLES:-

Let us assume the isotropic reflector to be located above the statistically rough surface (fig. 1.1) the reflector is illuminated by a receiving and transmitting antenna with a linear polarization of the field and with a wide pattern in the elevation angle plane. Then, according to the four-path propagation model [5, 6] the electric field vector at the antenna location can be expressed as -

$$E_0 \approx E_1 + E_{2,3} + E_4 \qquad \text{.................. (1)}$$

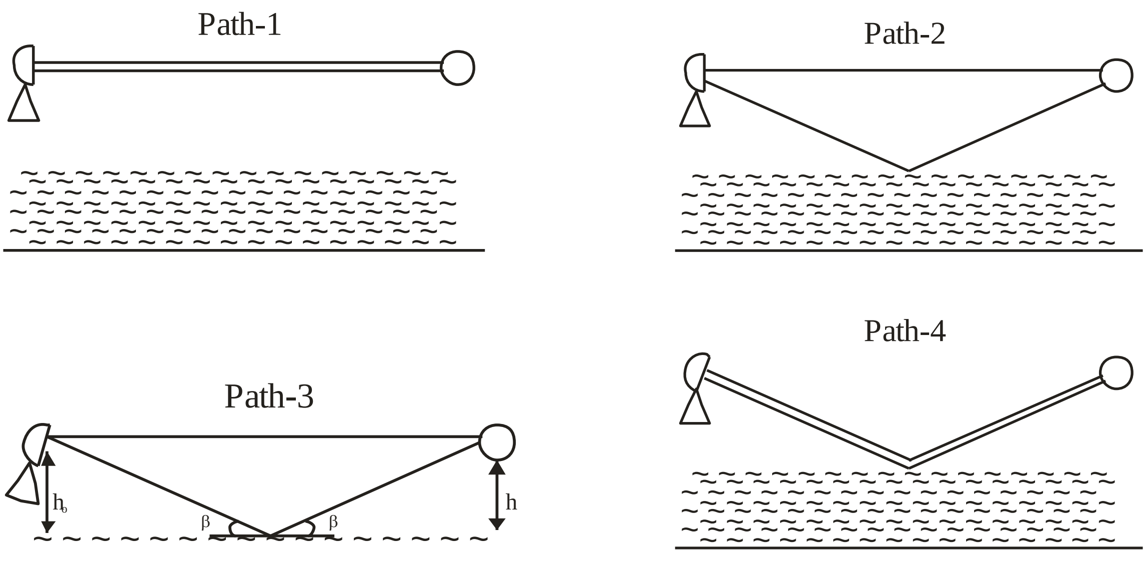

Fig. (1.1)

Where the lower indexes of the vectors indicate the number of the path (fig 1.1), the double indexes "2,3" are caused by the identity of paths 2 and 3 in thus approach.

In the far zone defined by the criterion [2], the scattering field is a spherical wave of the type

$$E_i \sim \frac{U_i}{R_i}\exp\left(jwt - jkR_i + jr\right), i = 0,1$$

$$E_i \sim \frac{U_i}{R_i}\exp\left(jwt - jkR_i + j\delta_i + jQ_i\right),$$

$$i = (2, 3), 4 \qquad \text{................ (1.2)}$$

Where R_i is the length of path number "U_i" is the amplitude of the scattered wave at the antenna location; δ_i is the phase shift formed due to the argument of the local scattering factor from the boundary surface; φ_i is a random phase whose value is determined by the roughness of the boundary surface; r_i is the phase of the wave; and k=(2π/ λ). Putting (1.2) into (1.1), the average intensity of the scattered field is

$$\frac{\overline{U_0U_0^*}}{R_0^2} \sqcup \frac{U_1U_2*}{R_1^2} + \frac{4U_{2,3}U^*_{2,3}}{R^2_{2,3}} + \frac{\overline{U_4U_4^*}}{R_4^2} +$$

$$+4\left\{\frac{\overline{U_{2,3}U_1^*}}{R_{2,3}R_1}\exp\left[jk\left(R_{2,3}-R_1\right)+j\left(\delta_{2,3}-\delta_1\right)+j\left(\varphi_{2,3}-\varphi_1\right)\right]\right\}$$

$$+2\,\mathrm{Re}\left\{\frac{\overline{U_4U_1^*}}{R_4R_1}\exp\left[jk\left(R_4-R_1\right)+j\left(\delta_4-\delta_1\right)+j\left(\varphi_4-\varphi_1\right)\right]\right\}$$

$$+4\,\mathrm{Re}\left\{\frac{\overline{U_{2,3}U_4^*}}{R_{2,3}R_4}\exp\left[jk\left(R_{2,3}-R_4\right)+j\left(\delta_{2,3}-\delta_4\right)+j\left(\varphi_{2,3}-\varphi_4\right)\right]\right\} \text{...... (1.3)}$$

where the upper line indicate statistical averaging; the upper index (∗) indicates the complex conjugate value and R_o is the horizontal range.

Let us perform a transformation in (1.3) corresponding to a first assumption: in the exponential, we leave only a linear term in the expansion and in the denominators we leave only the terms of wroth order this gives

$$k\left(R_{2,3}-R_1\right) \approx k\left(R_4-R_{2,3}\right) \approx \frac{4\pi hh_o}{\lambda R_o}$$

$$k\left(R_4 = R_1\right) \approx \frac{8\pi hh_o}{\lambda R_o}$$

$$R_{2,3}.R_4 \approx R_{2,3}^2 \approx R_1^2 \approx R_0^2 \qquad \text{............ (1.4)}$$

where h_o and h are the locations of the receiving-and-transmitting antennas and the reflector, respectively

For grazing elevation angles the following approximate equations can be written

$$\lambda_{2,3} \approx -\pi; \delta_4 \approx -2\pi \qquad \text{............ (1.5)}$$

The random phase φ can be determined in the following conditions: the statistics of the random roughness are Gaussian; the variation of roughness heights is large with respect to wavelength and the roughness is smooth and large compared to the wavelength, So, according to [3] we have

$$\varphi_4 = 2\varphi_{2,3} \approx 4k\xi\sin\beta \qquad \text{.............. (1.6)}$$

Where ζ in the ordinate of the random rough surface ζ (x, y) and β is the grazing angle of the scattered wave at the point of mirror reflection for a planar surface [fig 1.1]. For rough surfaces with large roughness, the point of mirror reflection is replaced in the center of the area of sufficient rescattering [8].

Using all taken assumptions and (1.4)-(1.6), we obtain

$$\overline{U_0U_0^*} \approx |U_1|^2 + 4\left|\overline{U_{2,3}^2}\right| + \left|\overline{U_4^2}\right|$$
$$-4\,\mathrm{Re}\left\{\overline{U_{2,3}U_1^*}\cos\left(\frac{4\pi hh_o}{\lambda R_o}\right)\exp\left(-2k^2\mu^2\sin^2\beta\right)\right\}$$
$$+2\,\mathrm{Re}\left\{\overline{U_4U_1^*}\cos\left(\frac{8\pi hh_o}{\lambda R_o}\right)\exp\left(-8k^2\mu^2\sin^2\beta\right)\right\}$$
$$-4\,\mathrm{Re}\left\{\overline{U_{2,3}U_4^*}\cos\left(\frac{4\pi hh_o}{\lambda R_o}\right)\exp\left(-2k^2\mu^2\sin^2\beta\right)\right\} \qquad \text{............. (1.7)}$$

An additional transformation in (1.7) can be made using -

$$\overline{U_{2,3}^2} = \left(\overline{U_{2,3}}\right)^2 + \Delta U_{2,3}^2$$
$$\left(\overline{U_{2,3}}\right)^2 \approx U_1^2\exp\left(-2k^2\mu^2\sin^2\beta\right) = \rho_s^2U_1^2$$

or,
$$\overline{\Delta U_{2,3}^2} = \rho_d^2U_1^2 \qquad \text{............... (1.8)}$$

where ρ_s and ρ_d are the mirror and diffuse reflection co-efficient from the rough surface with the variation μ^2 [9, 14, 12, 8, 4]. Performing the same analysis for the average intently of the fields propagation by the fourth path, the desired expression for influence of the rough boundary surface on the average intensity of the field scattered from the isotropic reflector is

$$V_{av}^4 = \frac{\overline{U_0U_0^*}}{U_1^2} \approx 1 + 4\left(\rho_s^2 + \rho_d^2\right) + \left(\rho_s^2 + \rho_d^2\right)^2$$
$$-4\rho_s\cos\left(\frac{4\pi hh_o}{\lambda R_o}\right)\exp\left(-2k^2\mu^2\sin^2\beta\right)$$
$$+2\rho_s^2\cos\left(\frac{8\pi hh_o}{\lambda R_o}\right)\exp\left(-8k^2\mu^2\sin^2\beta\right)$$
$$-4\rho_s^3\cos\left(\frac{4\pi hh_o}{\lambda R_o}\right)\exp\left(-2k^2\mu^2\sin^2\beta\right) \qquad \text{.............. (1.9)}$$

Equation (1.9) is a solution of the problem for any roughness-small and large. The trend of the propagation factor (1.9) versus the Rayleigh parameters, equal to $\chi = (\mu/\lambda)\sin\beta$, ($\chi < 0.05$) the height gain structure of V_{av}^4 has an explicitly expressed interference character with the correct alternation of lobes. For big values of χ ($\chi > 0.2$) the mentioned structure becomes homogeneous by height. The intermediate case of the height structure is given in fig (1.2). Here the experimental dependence $\rho_d(\chi)$ was used that was completed for $\chi < 0.2$ by testing data [14, 3, 8].

The key difference in (1.9) from previous reference is the continuous nature of the dependence V_{av}^4 in the interval $O \le \chi \le 1$. According to the well known model by Barton [9], [4], the influence of a rough boundary surface and the intensity of the signal scattered by the point wise reflector is expressed is the form

$$V_B = \rho_s V_o + V_d;\ \overline{V_d} = 0 \qquad \text{........... (1.10)}$$

where V_o is the function of the influence of the plane boundary surface, V_d is the diffuse component of the functional. $\overline{V_d}$ is the average value of this function taken to be equal to Zero. This model by Barton does not allow a continuous dependence V (χ) even through in the limiting cases $V_b^2 \approx V_{av}^2$.

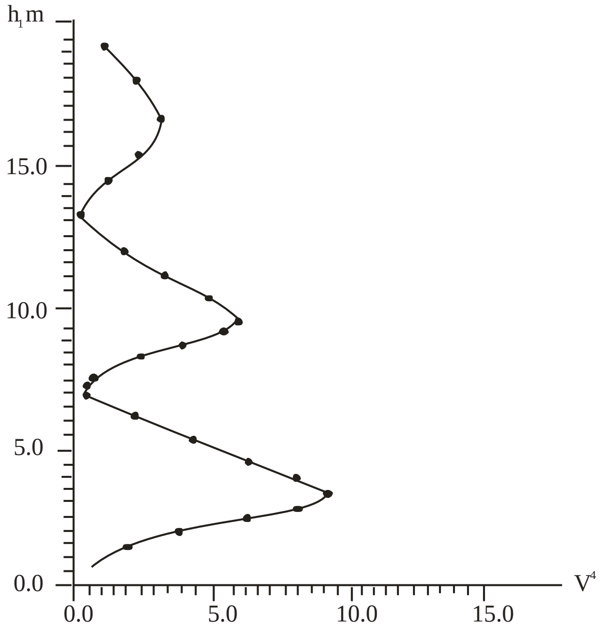

Fig-1.2

According to (1.9), the other peculiarity of the height-gain structure of V_{av}^{2} (χ) is that smoother lobe structure is obtained with increased height of the reflector. This trend is in accordance with the testing data [12, 3, 11] and is caused by increasing χ with the growth of h and also by a reduction in the area of sufficient reflections on the rough boundary surface.

1.3 CONCLUSION :-

Calculations of the propagation factor for ships show that the radar reflectivity for the same ship can vary due to the influence of the sea. This effect should be accounted during radar measurements of ships for grazing observation angles in the line-of-sight range.

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