MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

1 EFFECT OF NON GAUSSIAN WEATHER CLUTTER

2 ON PERFORMANCE OF CLUTTER-SUPPRESSION FILTERS

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4 ABSTRACT

In this paper it is investigated the performance of clutter suppression filters in non Gaussian clutter. The model chosen is Log-normal clutter and the filters considered are the optimum MTI filter and the linear prediction error filter. The performance of both types of filters in Gaussian clutter as expressed by the improvement factor (I.F) is computed for different number of pulses N and different values of correlation coefficient ρ . The results show that the optimal improvement factor is degraded for input non Gaussian clutter. While this situation can be improved if the complex weights are adjusted in correspondence with the covariance matrix of the Log-normal clutter. Comparison of performance of the two types of filters for different values of parameters is illustrated quantitavely in graphical form.

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I. INTRODUCTION :-

The performance of a radar is often limited by echoes from external clutter that are large compared with internal noise. There are three dominant sources of clutter [1] ; these are land clutter, sea clutter and weather clutter. The land clutter is due to the reflections from stationary objects on the ground whose data show for low grazing angles a broad amplitude distribution approximated by log-normal probability density and in some other situations is approximated by Weibull distribution. The envelope of the sea clutter echoes can be described by log-normal or contaminated-normal distribution when observed by high resolution radar at low grazing angles. Concerning weather clutter which is due to reflected radar signal from rain, snow, clouds and other atmospheric conditions this obeys usually log-normal distribution.

The need to eliminate clutter from the echo return is very real concern when requirement is to detect the presence of small moving targets. Three main optimization criteria can be used to design the rejection filters these are; maximization of the signal to interference ratio [2,3,7] , maximization of the improvement factor [4] and linear prediction of clutter samples [5]. Previous works attempted to use a filtering approach to suppress clutter under the assumption that the clutter has a Gaussion distribution but other different distributions mentioned above have not been treated in a quantitative manner.

In this paper we shall be confined with two types of clutter suppression filters which are; The optimum MTI filter maximizing the improvement factor, and linear prediction error filter based on linear prediction of clutter samples. The behaviour of these two types of filters will be compared for Gaussian clutter in section (II) then it will be presented in a quantitive manner. The degradation of performance of the two types of filters when the clutter is non-Gaussian clutter obeying log-normal distribution will be treated in section (III). It will be shown also the improvement in performance if the parameters of the two filters will be modified to cope with the parameters of the lognormal clutter .

II. CLUTTER SUPPRESSION FILTER PERFORMANCE IN GAUSSIAN CLUTTER :-

A. Optimum MTI Filter:-

The approach for designing optimum MTI filter in this section is directed to the criterion of maximization of the improvement factor (I.F) [6]. It is assumed that the clutter of interest is Gaussian with Gaussian power spectral density function which is given by

$$G(f) = \frac{1}{\sqrt{2\pi}\,\sigma_c} \exp\left(-\frac{f^2}{2\sigma_c^2}\right) \qquad (1)$$

where f is the doppler frequency and σ_c is the standard deviation. Without loosing generality, we have assumed that the mean doppler frequency is zero. Accordingly, the elements of the covariance matrix A is given by [4]

6

$$a_{ij} = \rho^{(i-j)^2} \qquad (2)$$

where ρ is the clutter correlation coefficient. Target echo can be described by a vector s

$$s = \alpha \begin{bmatrix} \exp(j\varphi_1) \\ \exp(j\varphi_2) \\ \vdots \\ \exp(j\varphi_k) \\ \vdots \\ \exp(j\varphi_N) \end{bmatrix} \qquad (3)$$

where $\varphi_k = 2\pi f_s T k$ is the phase of the Kth component of the signal vector s , α is the signal amplitude, f_s is the doppler signal frequency and T is the sampling interval. Under the assumption that f_s is uniformly distributed in interval (0, 1/T). The signal covariance matrix S is given as

$$S = \alpha^2 I \qquad (4)$$

where α^2 is the target signal power and I is the identity matrix. The MTI improvement factor (I.F) is given in the matrix form as

$$I.F = \frac{W^+ W}{W^+ A W} \qquad (5)$$

where W is the vector of the filter complex weights, A is the clutter covariance matrix and W^+ the complex conjugate transpose of W (see Fig.1)

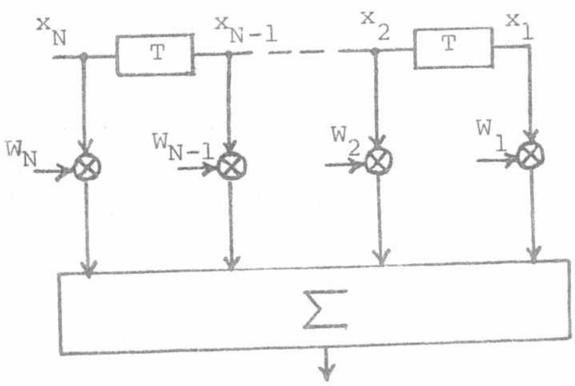

Fig.1. A nonrecursive MTI filter

The maximization of the I.F factor leads to an optimum filter weights [5] given as

$$W_o = y_m \qquad (6)$$

Where y_m is the eigenvector associated with the minimum eigen value λ_m of matrix A

B. Linear Prediction error Filter :-

The linear prediction error filter is based on the linear prediction of the clutter samples. The x_N sample can be predicted from the linear weighted summation of the (N-1) past samples as given in Fig.2

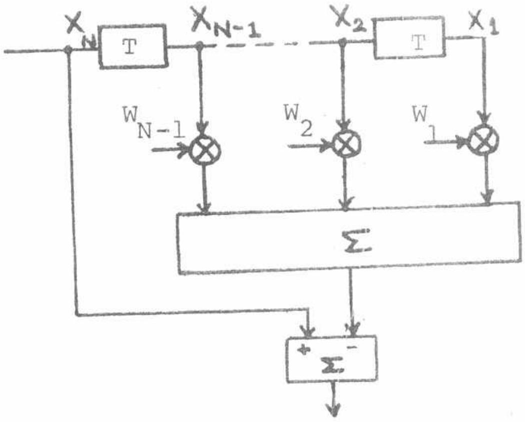

Fig.2. LPE Filter

let this estimate of x_N be $\hat{x}_N$ where

$$\hat{x}_N = \sum_{k=1}^{N-1} W_k \, x_k \tag{7}$$

The error between the actual value x_N and the predicted value $\hat{x}_N$ is given by

$$e_N = x_N - \hat{x}_N \tag{8}$$

The mean square error is given by

$$e_{m.s} = E\left[\left| x_N - \hat{x}_N \right|^2 \right] \tag{9}$$

For the case of clutter having much power than the signal and by using the orthogonality principle [5] we obtain the normal equations

$$r - \bar{A}\,\bar{W} = 0 \tag{10}$$

where

$$r = \begin{bmatrix} a_{1N} \\ a_{2N} \\ \vdots \\ a_{kN} \\ \vdots \\ a_{N-1\ N} \end{bmatrix} \tag{11}$$

r is the covariance vector, $\bar{A}$ is the reduced clutter covariance matrix and $\bar{W}$ is the reduced vector of complex filter weights.

The optimal weight vector is given by

$$\bar{W}_o = \bar{A}^{-1}\, r \tag{12}$$

6

C. Performance Evaluation for Gaussian Clutter:-

The above two methods are compared through computation of the optimal I.F factor versus the clutter correlation coefficient ρ in the interval $\rho = 0.6$ to 0.95 for different number of canceling pulses N with N = 3,4,5 the results are illustrated in Fig.3,7 and 11.

The optimum MTI is represented by solid curves while LPE filter by dashed ones. The results show that the LPE filter deviates only partially from optimum MTI.

III. FILTER PERFORMANCE FOR NON-GAUSSIAN CLUTTER:-

In this section we shall investigate the performance of the two types of clutter suppression filters considered in section (II), for the case of non Gaussian clutter. Considering the model of log-normal clutter which describes most types of weather clutter then we can see that:-

A. Introducing this log-normal clutter described by covariance matrix A_L to the filters mentioned in section (II) which are optimized for Gaussian clutter, we remark that performance exhibites appreciable degradation in comparsion with Gaussian clutter case expressed in form of loss in I.F factor Δ_1 . We demonstrate this degradation through computer analysis of this situation whose results are illustrated in Figure 4,8 and 12 for the same values of ρ and N as in Fig.3,7 and 11 for Gaussian clutter case

B. We have obtained an appreciable improvement in the performance of these two types of filters for the case of non Gaussian clutter through readjusting the complex filter weights in correspondance with covariance matrix A_L of the log-normal clutter. While the computer simulation of this situation has resulted in some degradation Δ_2 in I.F factor with respect to the Gaussian case as it is seen from Fig. 5,9 and 13.

Neverthless this approach has indicated an improvement measured by $(\Delta_1 - \Delta_2)$ [dB] in comparsion with case mentioned in part (a) of this section.

IV. CONCLUSIONS

In this paper, it is investigated the effect of log-normal weather clutter on performance of clutter suppression filters. The considered filters are optimum MTI based on maximization of I.F factor and LPE filter based on linear prediction of clutter samples. Computer evaluation shows that:-

1) The algorithm of LPE filter which is much less complex than optimum MTI filter, in most practical cases gives a performance very close to the optimum MTI filter for Gaussian clutter when clutter correlation coefficient ρ is greater than 0.8.

2) For the non Gaussian clutter case, modeled by log-normal distribution, the filters exhibits degradation in performance Δ_1 which shows for N = 3 better performance of optimum MTI in comparison with LPE filter. For $N > 3$ the same conclusion applies as far as $\rho > 0.9$ while for $\rho < 0.9$ LPE filter exhibits better performance.

3) If the parameters of the filters are modified in correspondence with the parameters of the log-normal clutter, the filters show improvement as it is seen from curves of Δ_2 in Fig.5,9 and 13. The degradation in performance for $N > 3$ shows that optimum MTI filter is better than LPE Filter. While for N=3 LPE filter is better - see also Fig.6 for $\Delta_1 - \Delta_2$

4) This improvement expressed by a value of $\Delta_1 - \Delta_2$ as illustrated in curves of Figs. 10 and 14 show that optimum MTI is better than LPE filter for $N > 3$ and $\rho < 0.9$. While for $\rho > 0.9$ LPE filter is better.

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Number of cancelling pulses N=3

——— Optimum MTI

---- Linear prediction error filter

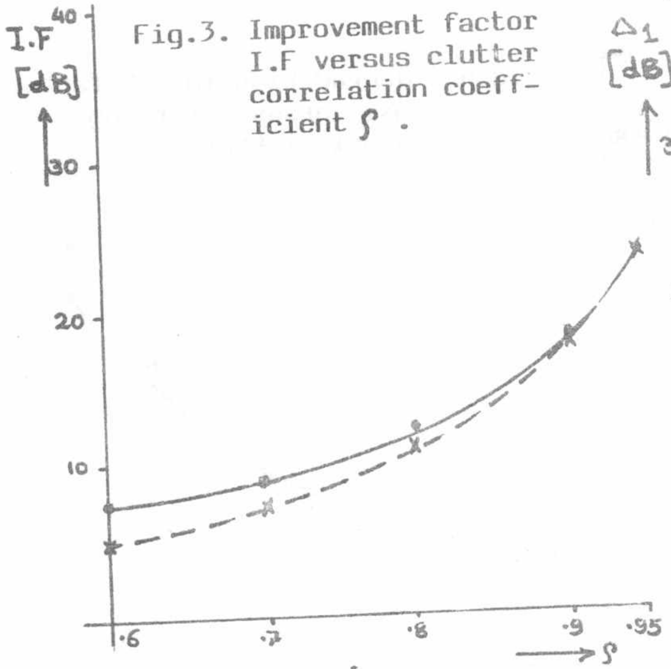

Fig.3. Improvement factor I.F versus clutter correlation coefficient ρ .

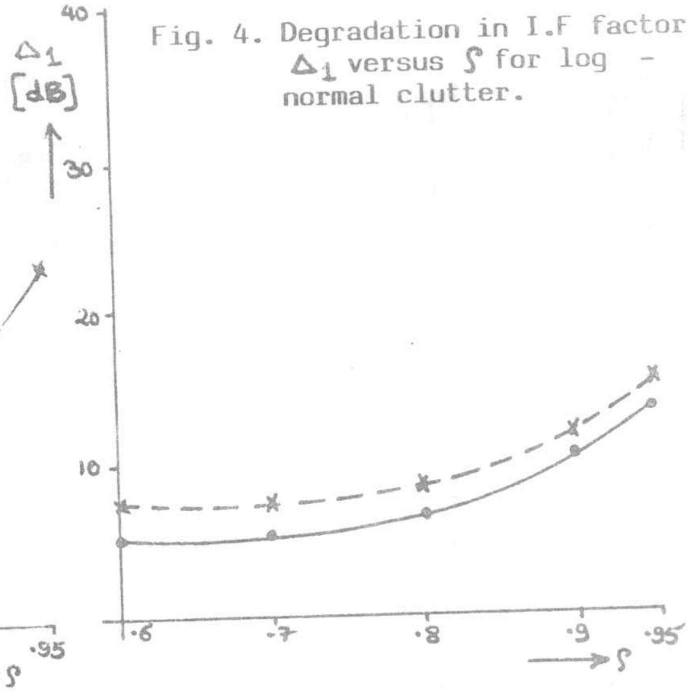

Fig. 4. Degradation in I.F factor Δ_1 versus ρ for log - normal clutter.

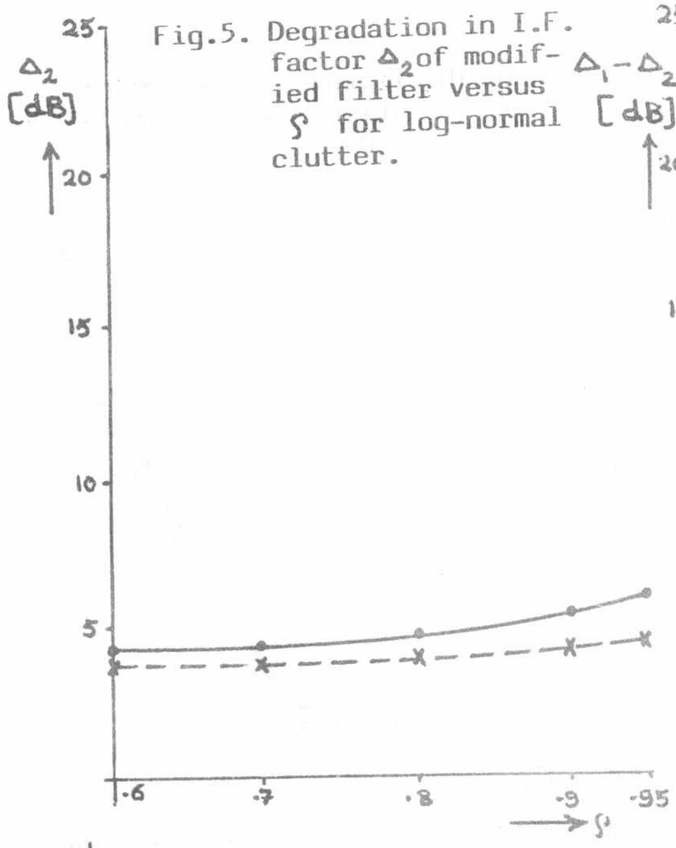

Fig.5. Degradation in I.F. factor Δ_2 of modified filter versus ρ for log-normal clutter.

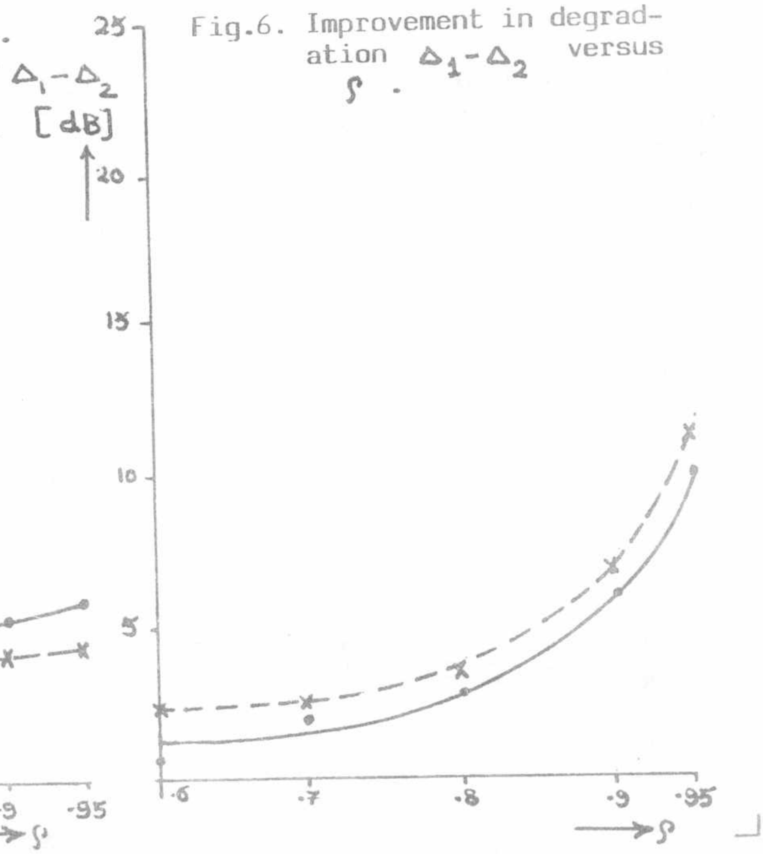

Fig.6. Improvement in degradation $\Delta_1 - \Delta_2$ versus ρ .

Number of cancelling pulses N=4

——— Optimum MTI

--- Linear prediction error filter

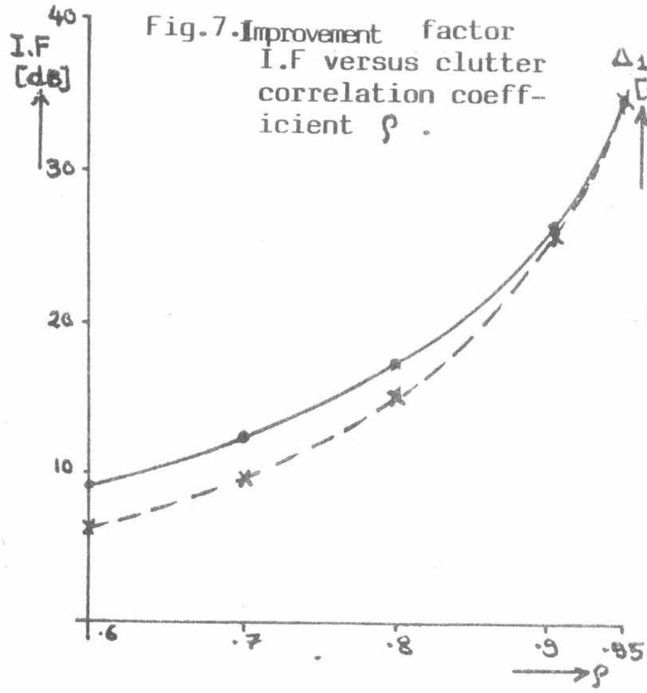

Fig.7. Improvement factor I.F versus clutter correlation coefficient ρ .

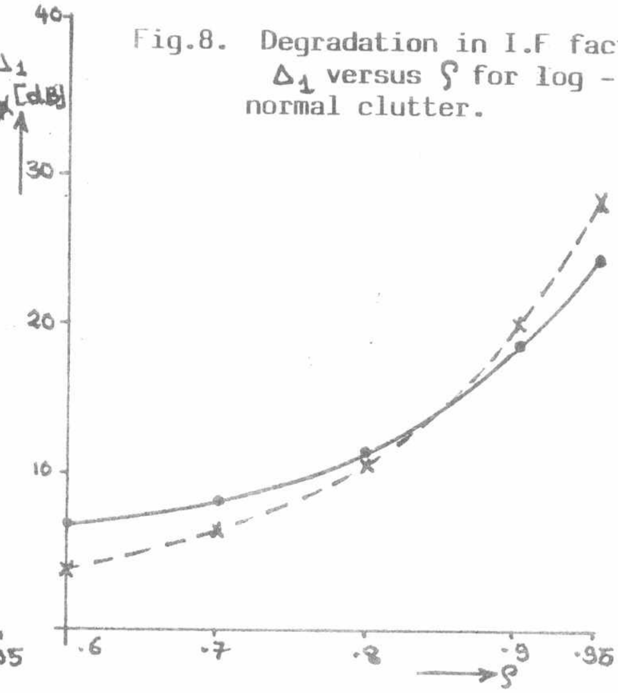

Fig.8. Degradation in I.F factor Δ_1 versus ρ for log - normal clutter.

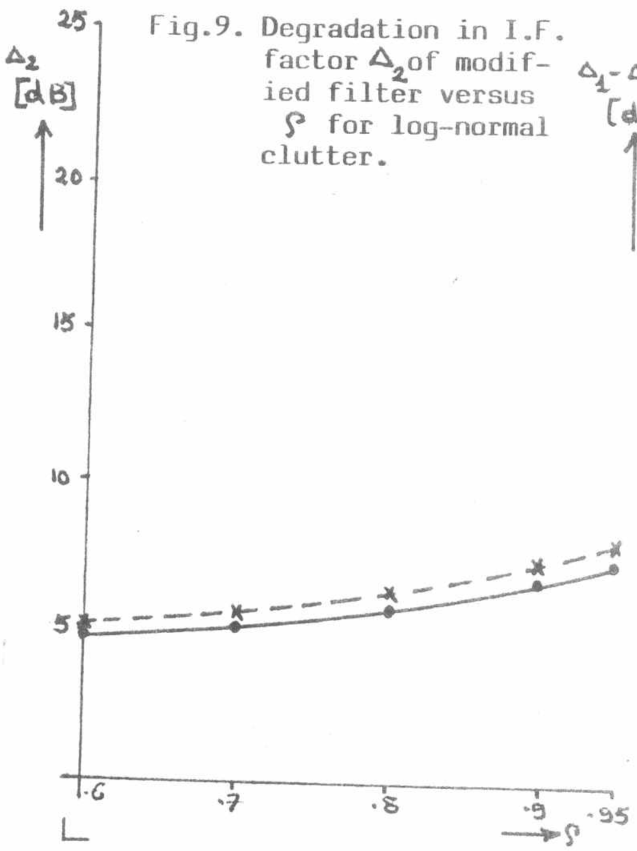

Fig.9. Degradation in I.F. factor Δ_2 of modified filter versus ρ for log-normal clutter.

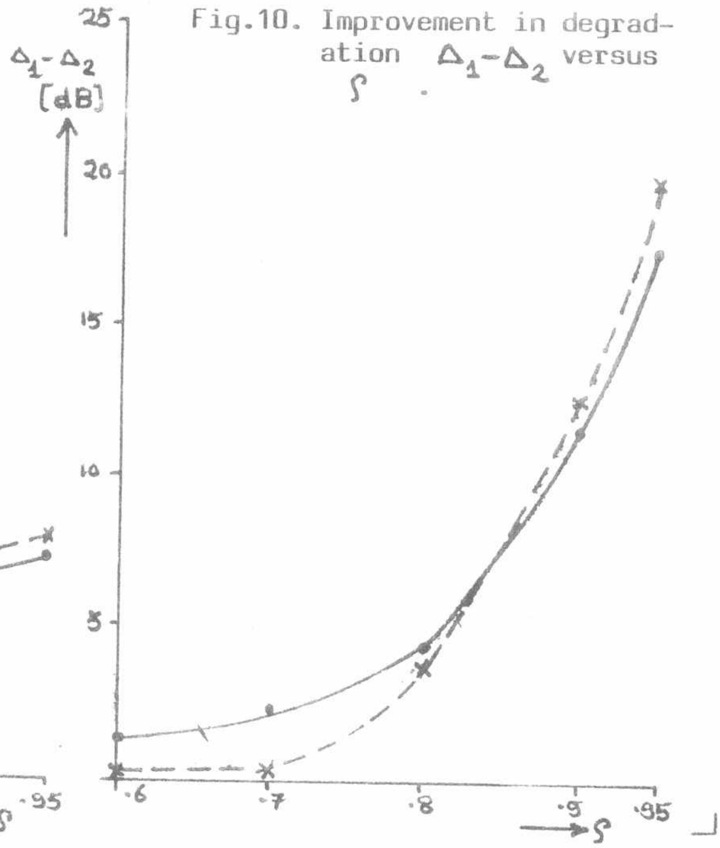

Fig.10. Improvement in degradation $\Delta_1-\Delta_2$ versus ρ .

Number of cancelling pulses N=5

—— Optimum MTI

--- Linear prediction error filter

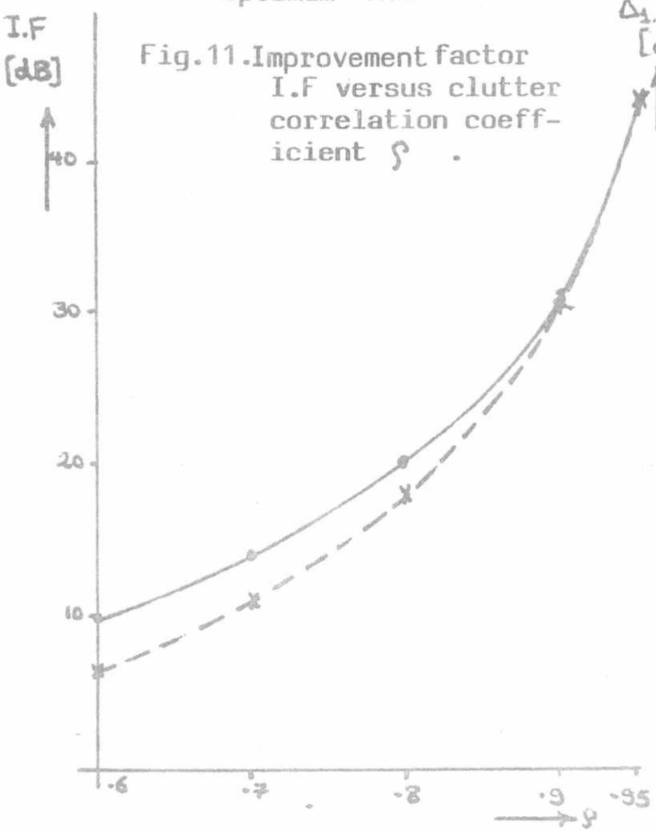

Fig.11. Improvement factor I.F versus clutter correlation coefficient ρ .

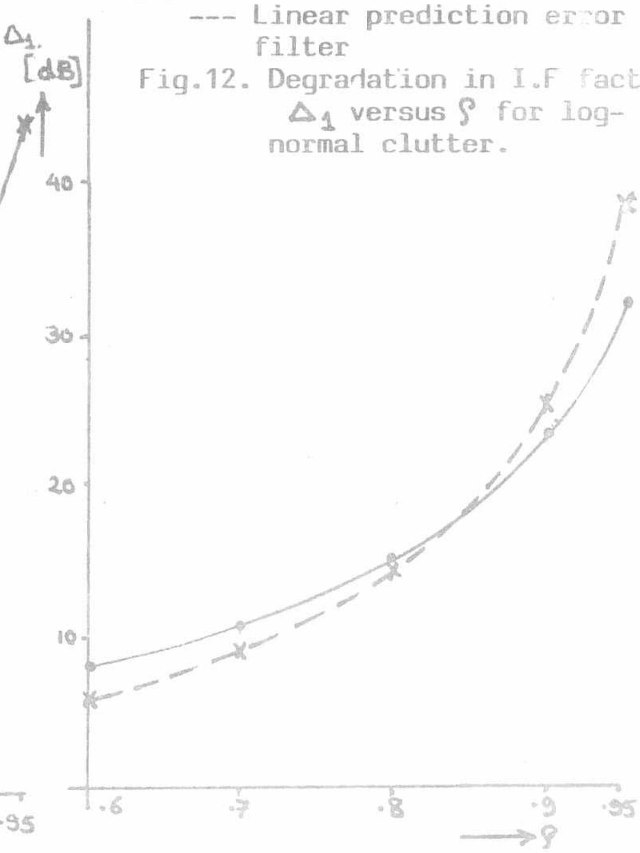

Fig.12. Degradation in I.F factor Δ_1 versus ρ for log-normal clutter.

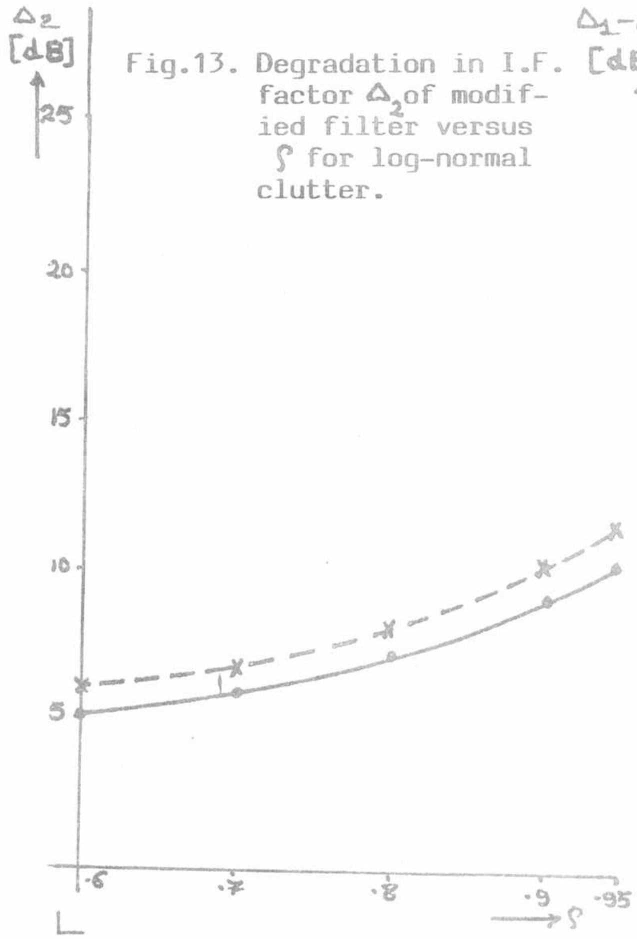

Fig.13. Degradation in I.F. factor Δ_2 of modified filter versus ρ for log-normal clutter.

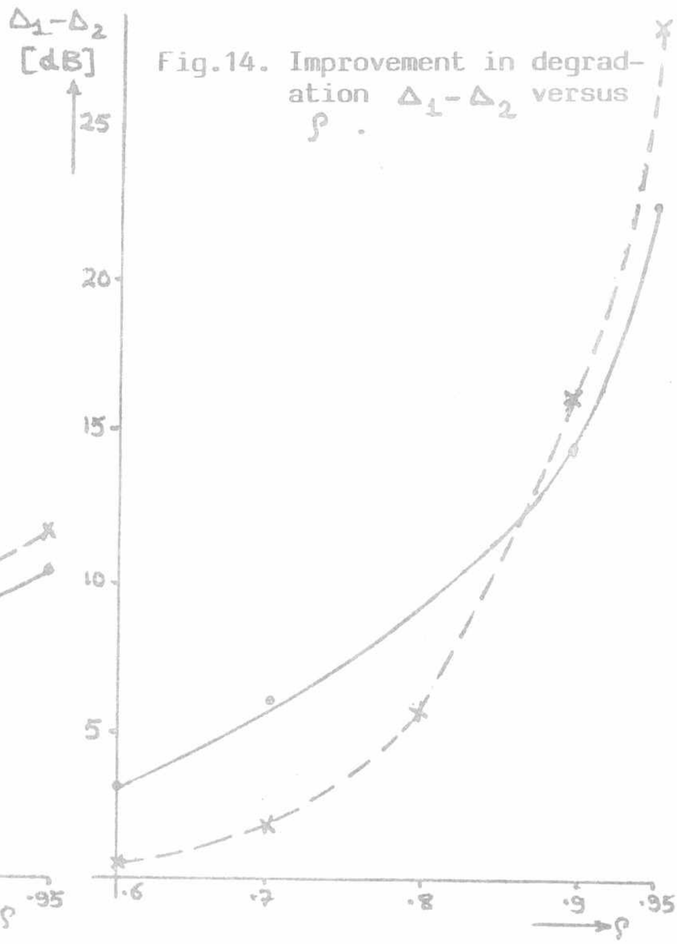

Fig.14. Improvement in degradation $\Delta_1 - \Delta_2$ versus ρ .