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MODELLING OF SONAR SYSTEMS FOR FISH ABUNDANCE MEASUREMENTS

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INTRODUCTION

An earlier paper[1] described the computer modelling of a simple echo-sounder system and the use of this model to estimate the performance of the system in such applications as fish abundance measurement. The results were sufficiently encouraging to justify the extension of the model to simulate an electronically scanned sonar system similar to those developed at Loughborough University and elsewhere[2].

DESCRIPTION OF MODEL

In reference (1) it is shown that the output of a simple echo sounder can be represented by the convolution of two functions viz:-

$$v(R) = h(R) * \sum_i T_i \, \delta(R - R_i)$$

where $h(R)$ is the transmitted pulse shape, R_i is the range of the i^{th} target and T_i is its amplitude taking into account all the factors which would control its amplitude including its position in the beam. The output waveform of the echo sounder receiver is, of course, a function of time but since the display is calibrated in range it is convenient to express the output as a function of range. A typical shape for the transmitted pulse is a sine wave with a raised-cosine envelope which in normalised units would be

$$h(R) = \tfrac{1}{2}\left(1 - \cos \frac{2\pi R}{\Delta}\right) \cos R \qquad 0 < R < \Delta$$

$$= 0 \qquad \text{elsewhere}$$

Δ is thus the pulse length in range units.

The beam pattern of the echo sounder transducer array is assumed Gaussian for convenience but it would be a relatively trivial alteration to introduce any other practical beam shape.

It would lengthen this paper considerably to reproduce a description of the operation of an electronically scanned sonar system and there are many papers containing such details, references (2) - (5).

The beam pattern of an array of N elements is given by $D(\psi) \cdot D_o(\psi)$ where

$$D(\psi) = \frac{\sin N\psi/2}{\sin \psi/2}$$

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N = number of elements

$\psi = \frac{2\pi d}{\lambda} \sin\theta$

d = spacing between centres of elements

$D_o(\psi)$ = beam pattern of an individual element

In an electronically scanned system the output of the array for a plane wave arriving at angle θ is proportional to

$$v(t) = D(\psi - pt)\ D_o(\psi)$$

where p is the scanning frequency (rads/sec). An example of this waveform is shown in Figure 1.

The time variable can be expressed in units of range by substituting

$$R = \frac{ct}{2}$$

so $$U(R) = D(\psi - \frac{2p}{c} R)\ D_o(\psi)$$

and in the normalised system $\frac{2}{c} = 1$ so that

$$U(R) = D(\psi - pR)\ D_o(\psi)$$

The output for a target at normalised range R_i, of strength T_i and angle in the scanned direction of θ_i, will be given by:

$$v(R) = \{h(R) * T_i\ \delta(R - R_i)\} \cdot D(\psi_i - pR)$$

T_i can absorb the factor $D_o(\psi_i)$

A typical curve for a single target is shown in Figure 2 and a typical output for a number of targets is shown in a pseudo three-dimensional form in Figure 3. Figure 4 shows a ring of targets which is simulating a situation reported by Dr. Cook in Reference (6).

RESULTS

The possible use of the system in fish abundance measurement was tested in the same way as outlined in Reference (1). A random number of targets were generated with random strengths, ranges and angles and the output energy determined. The calculation allowed the number of targets to be estimated and then compared with the actual number. Results for a number of cases are

shown in Figures 5 - 7. For comparison a curve for the single echo sounder is given and the significant improvement by the use of the electronic scanning system is well illustrated.

REFERENCES

(1) GRIFFITHS, J.W.R. and SMITH, J.P., 'A Model of an Echo-sounder for fish abundance measurements', Proc. of Conf. "Acoustics in Fisheries", Hull, Sept. 1978.

(2) GRIFFITHS, J.W.R., PRATT, A.R. and STEVENS, P.J., 'High Resolution Sonar Systems', Proc. of Oceanology International '78, Brighton 1978.

(3) VOGLIS, G.M. and COOK, J.C., 'Underwater Application of an Advanced Acoustic Scanning Equipment', Ultrasonics 4, pp 1 - 9, Jan. 1966.

(4) MITSON, R.B. and COOK, J.C., 'Shipboard Installation and Trials of an Electronic Sector Scanning Sonar', Proc. of Conf. on Electronic Engineering in Ocean Technology, Swansea, Sept. 1970.

(5) HOLLEY, M.L., MITSON, R.B. and PRATT, A.R., 'Developments in Sector Scanning Sonar', Proc. of Conf. "Instrumentation in Ocean Technology". Bangor, 1975, pp 138-153.

(6) COOK, J.C. and RUSHWORTH, A., 'Digital Signal Processing of High Resolution Within-Pulse Sector Scanning Sonars', Proc. of Conf. "Progress in Sector Scanning Sonar", Lowestoft, December 1979.

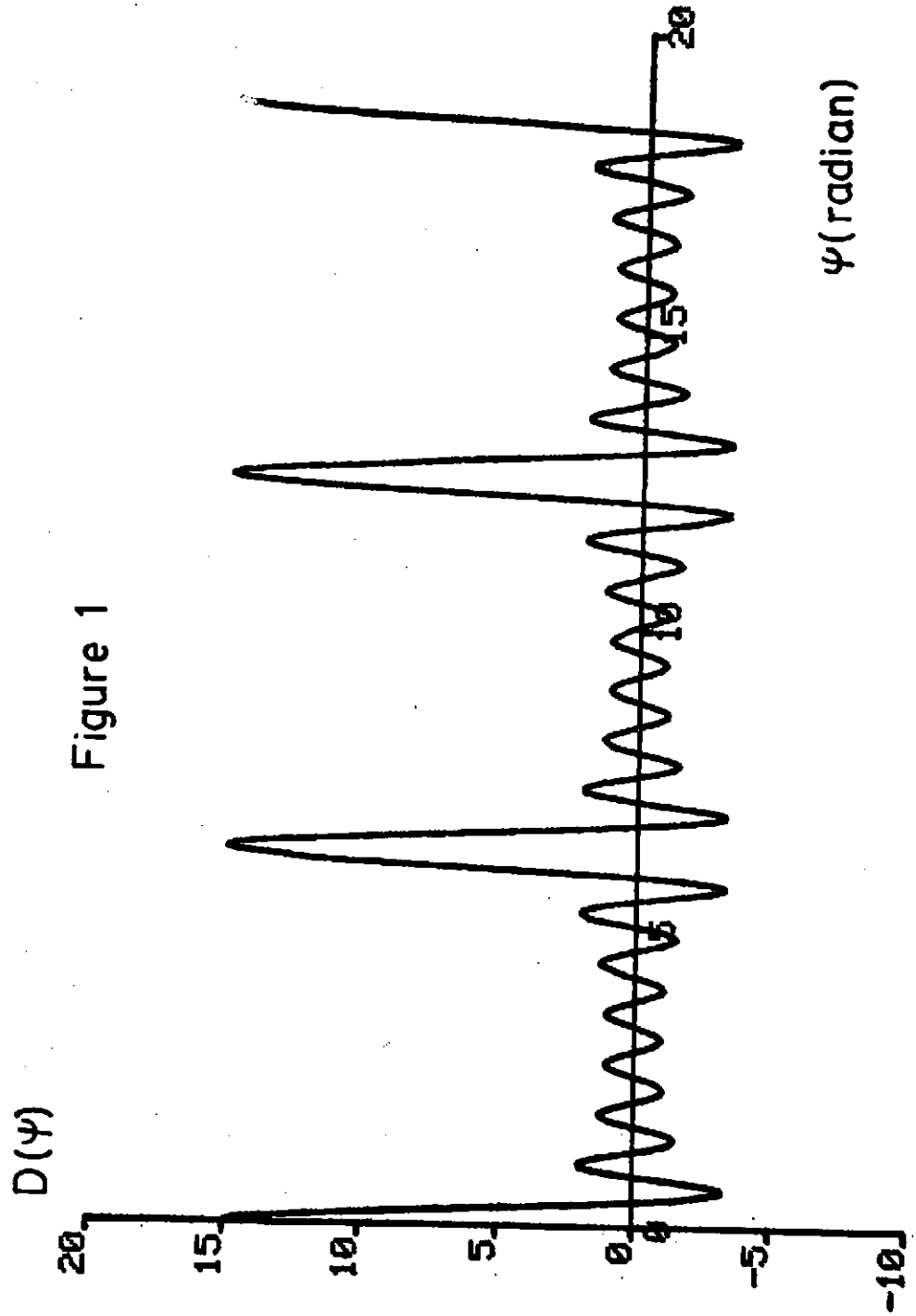


Figure 1

Figure 2

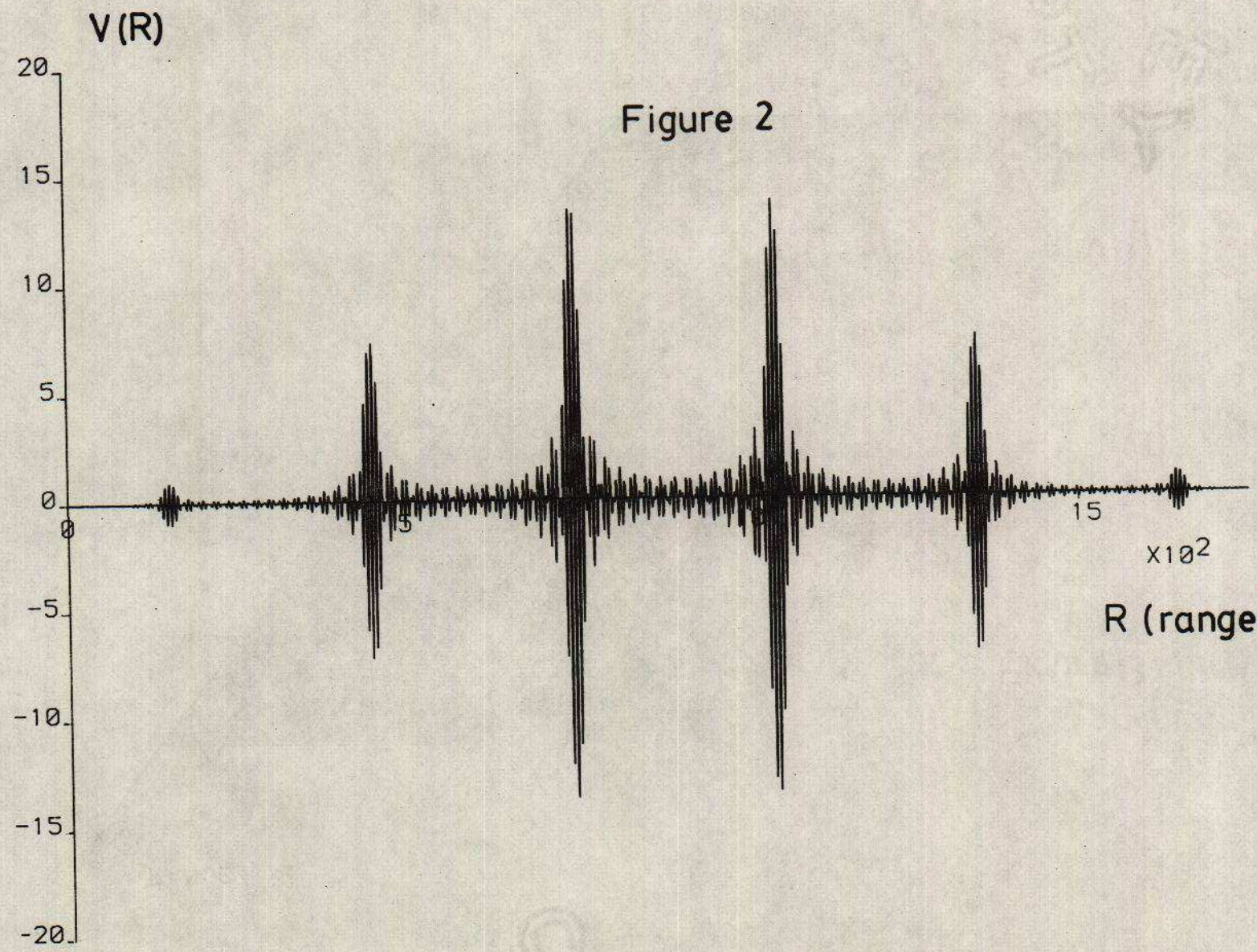
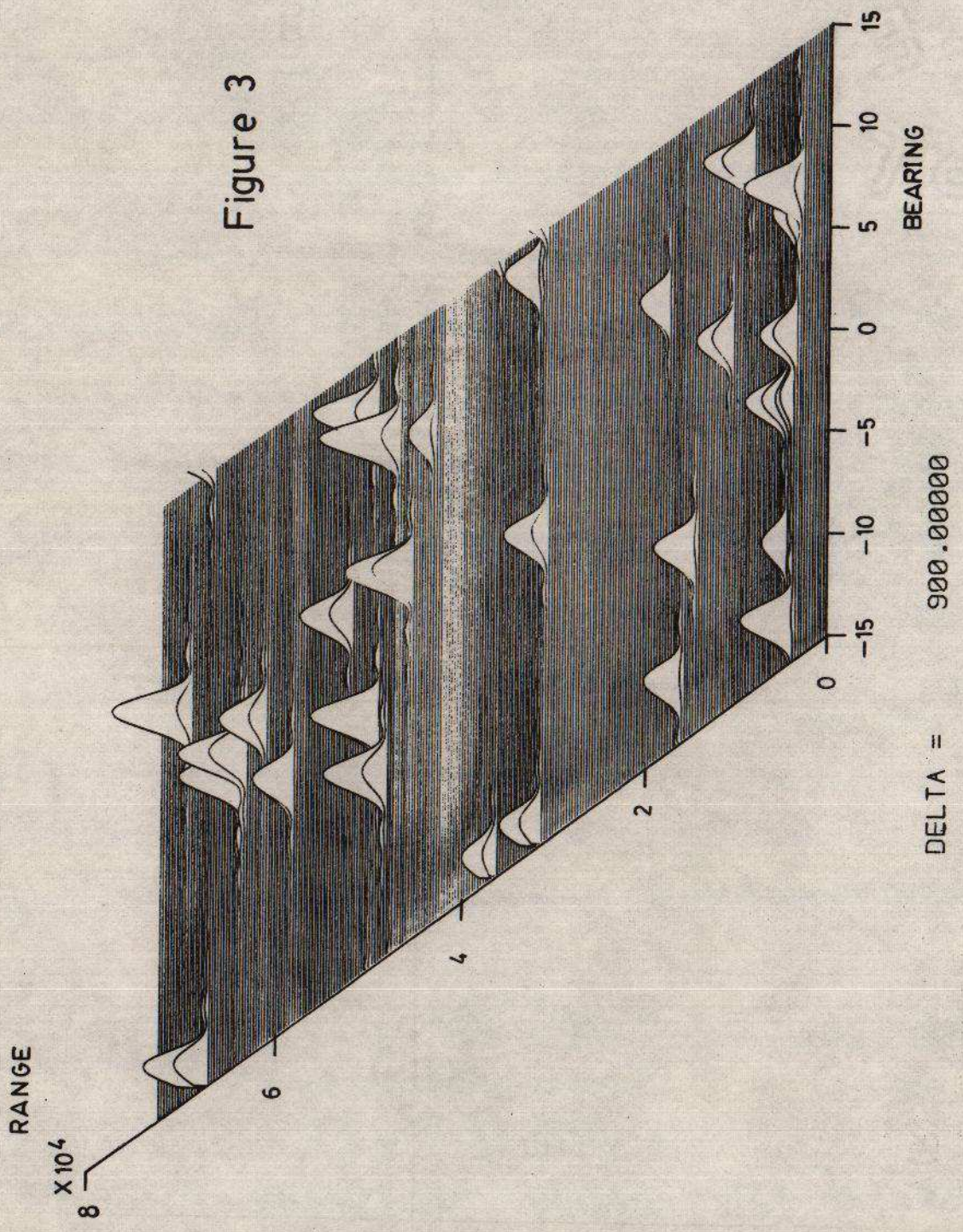


Figure 3



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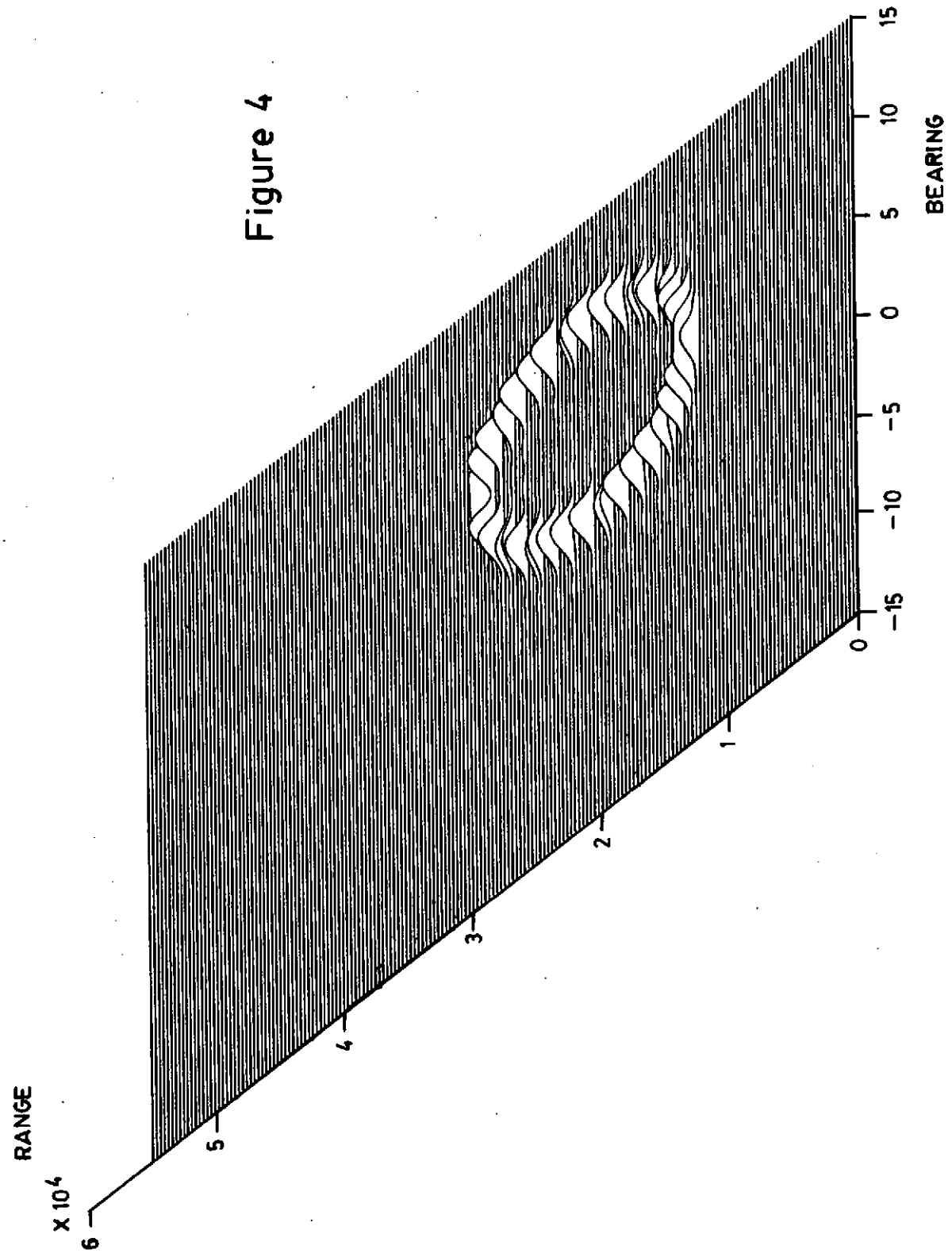

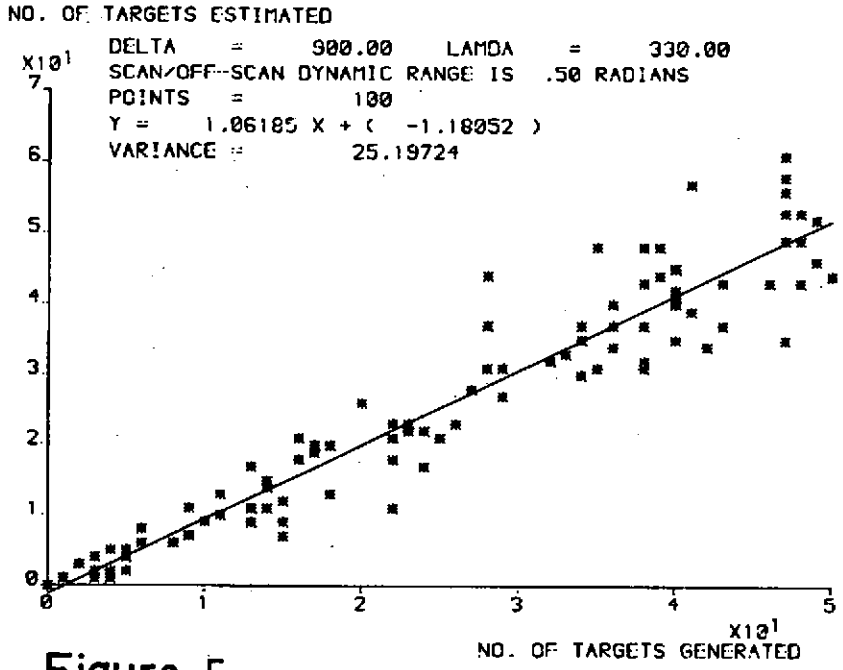
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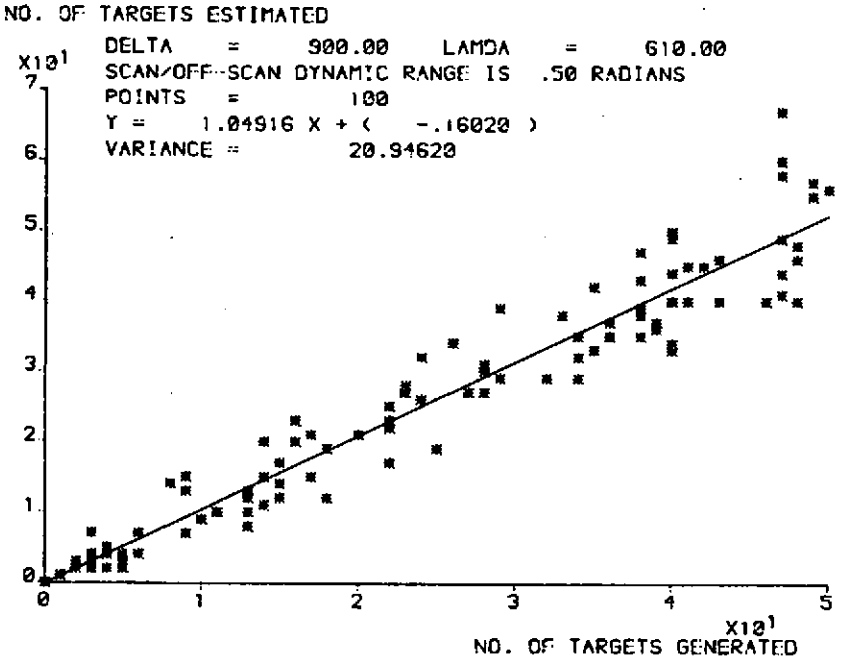
X10¹
NO. OF TARGETS GENERATED

Figure 5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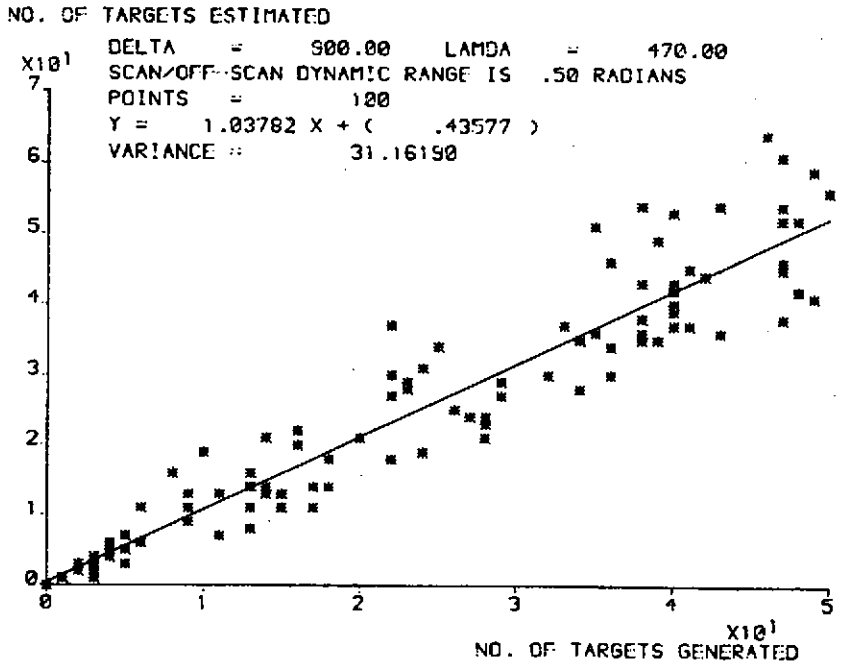
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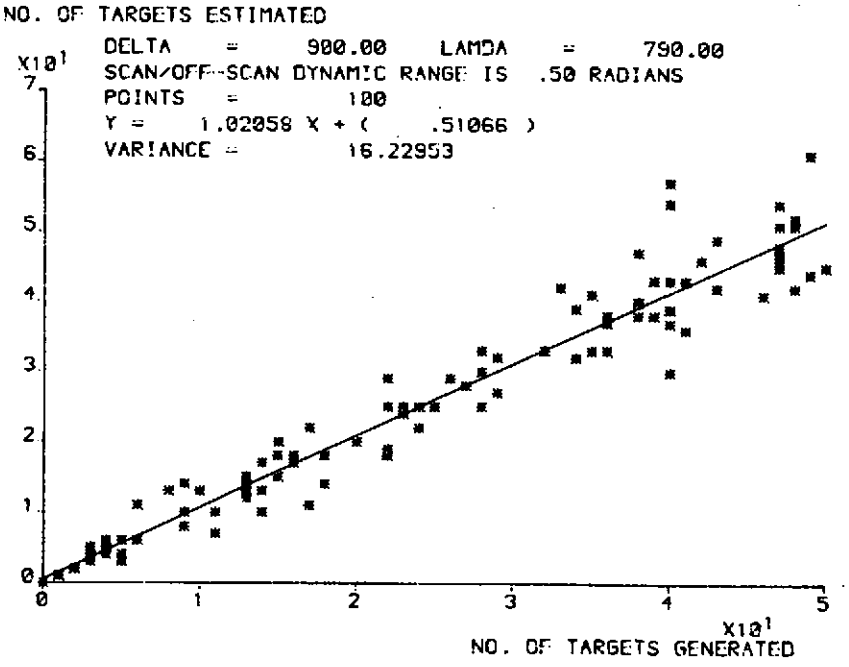
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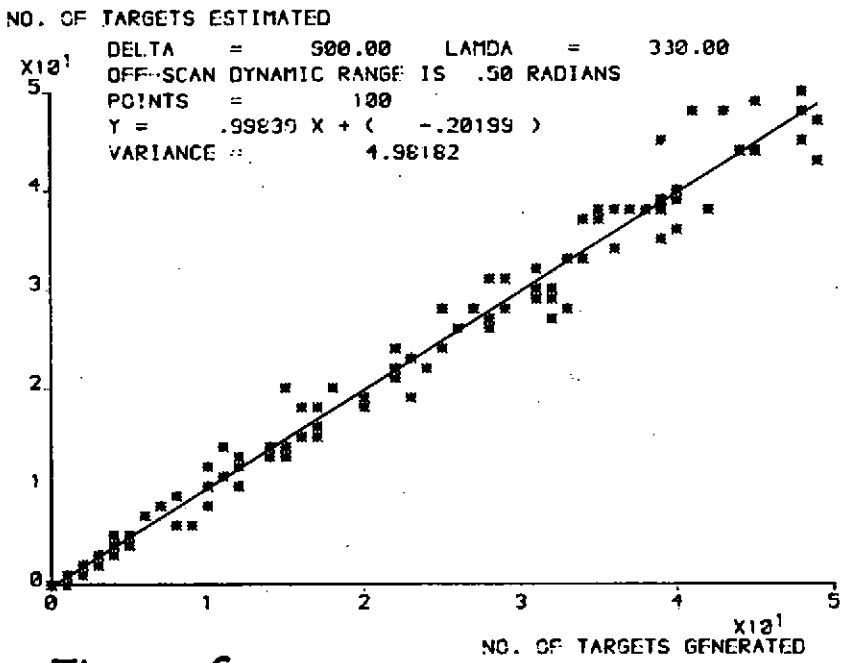
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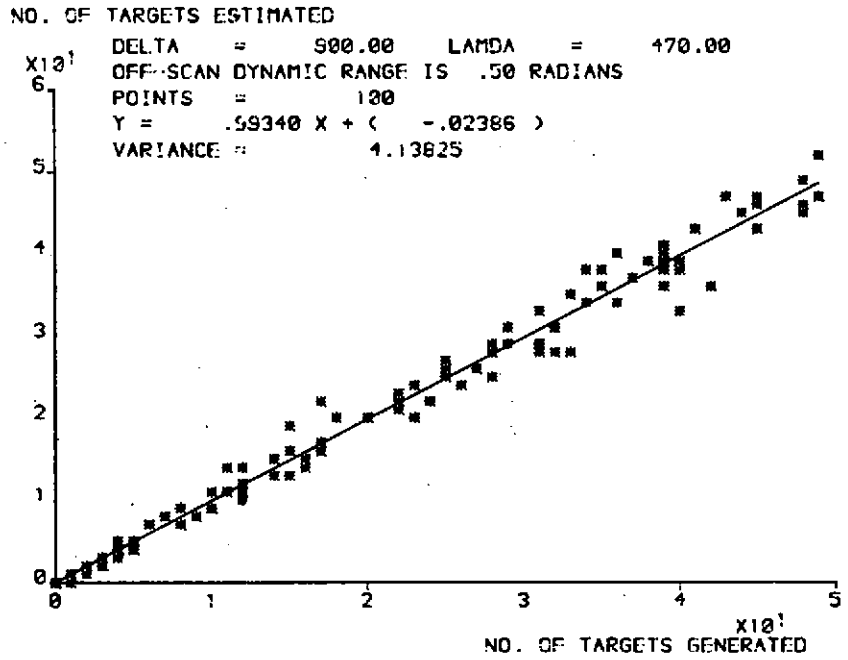
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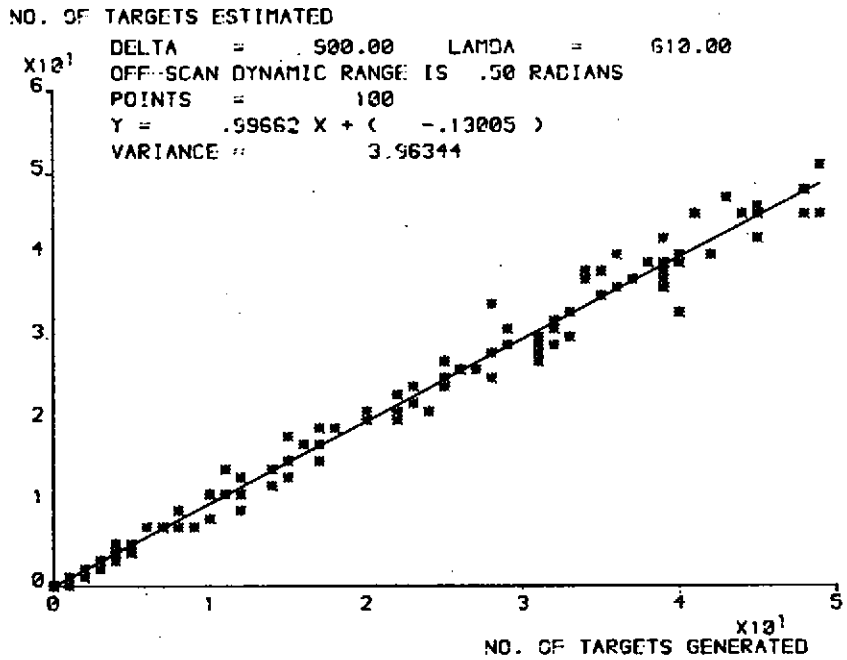
Figure 6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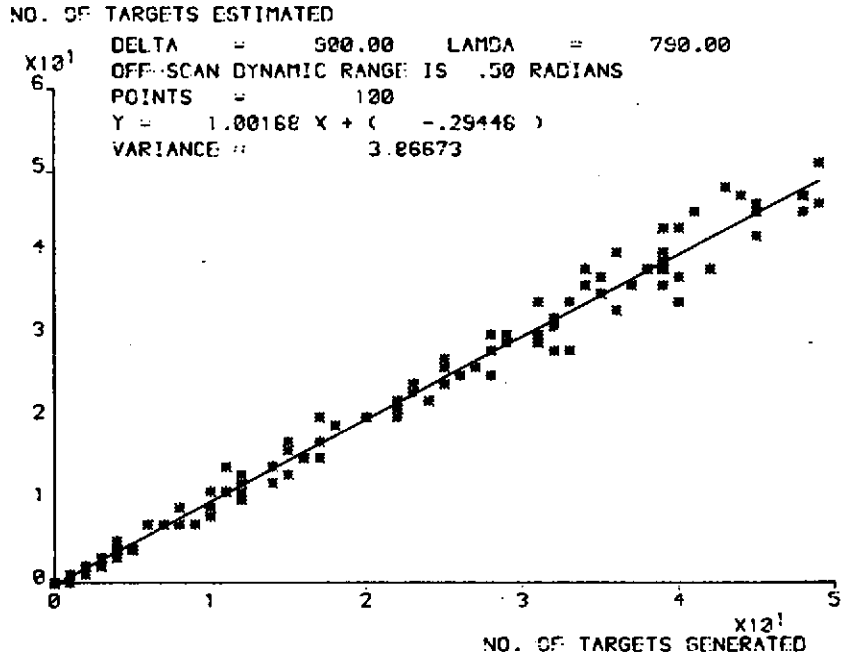
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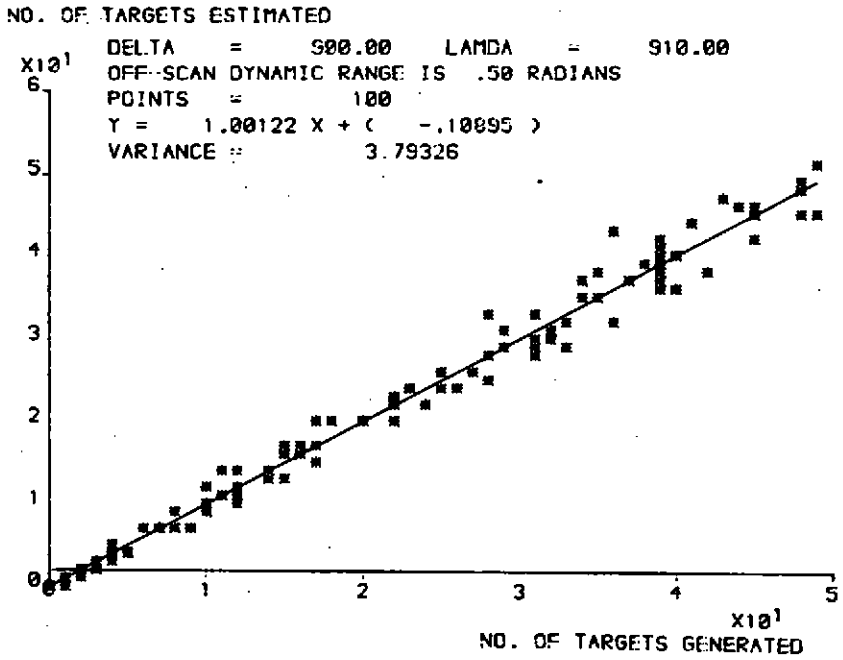
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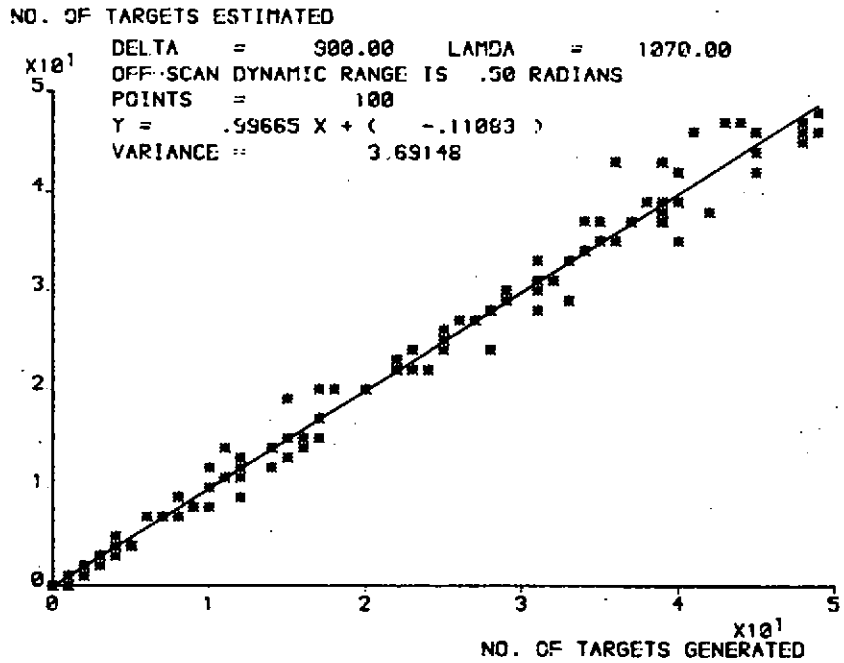
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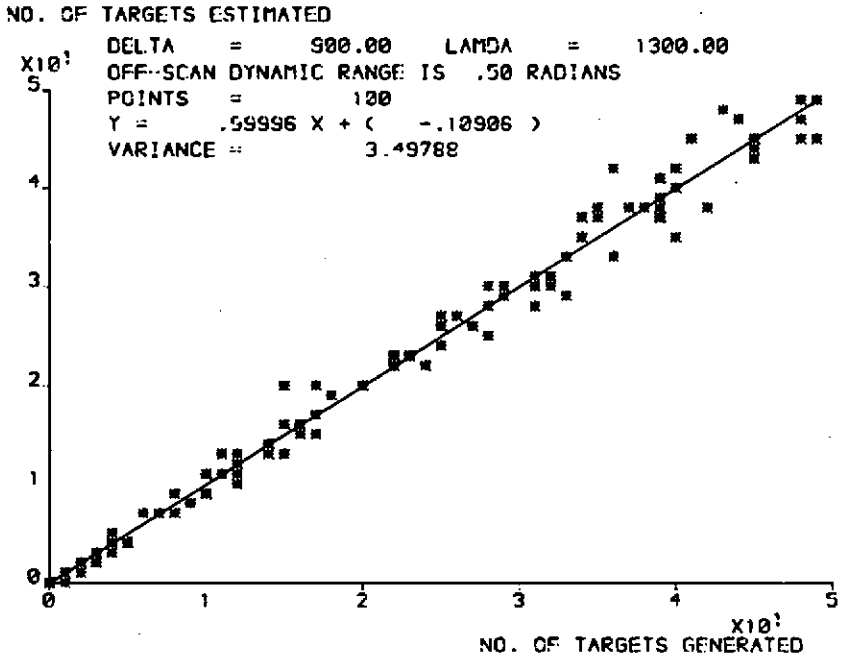
Figure 7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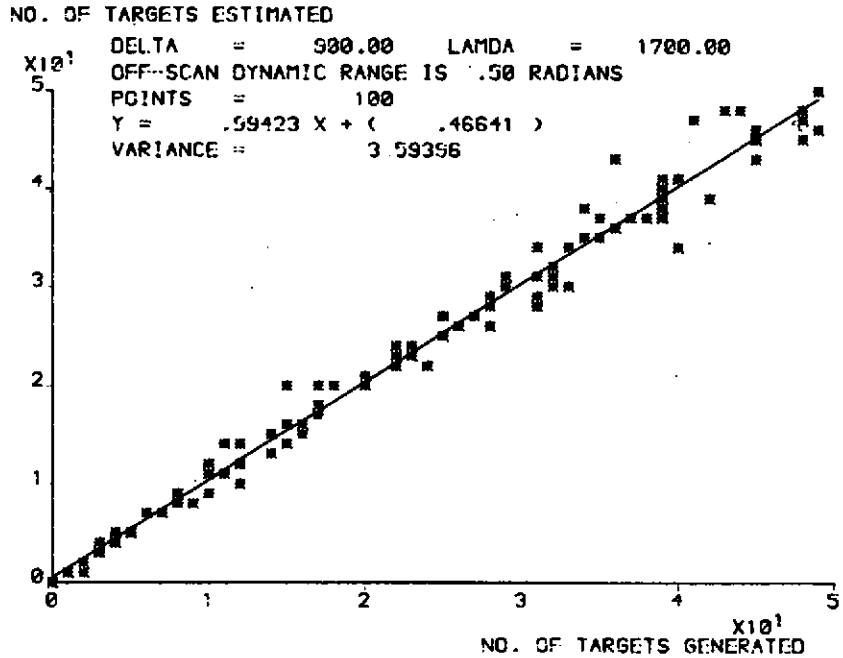
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