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ABERRATION OF 4-AND 8-LOOP-MONITORS

by

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ABSTRACT

The aberrations of several loop-monitors for measuring the displacement of an electron-beam in an accelerator are calculated. The picture produced by induced signal of an orthogonal lattice in a plan perpendicular to beam direction is distorted similar to distortion by optical lenses. The distortion can be reduced by using 8-Loop-instead of 4-Loop-Monitors.

INTRODUCTION

Usually pick-up electrodes or loop-monitors are used to detect the position of the electron beam in an accelerator relative to the ideal beam center line. With loop-monitors the magnetic field of the beam induces a signal to the loop, with pick-up electrodes on the contrary the electric field of the beam interacts with the electric field of the monitor. Though special formed pick-up electrodes with linear response are known [1] the sensitivity is small conspared with loop-monitors. Two different 4-loop-configurations are used [2,3] (fig. 1 and 2).

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[1] Goldin, L. L.: Pribory i Technika Eksperimenta 1966, No. 4, pp 18 - 21 (CERN Translation 66-6)

[2] Anderson, B. and Matin, S. M.: Symposion on Beam Intensity Measurement, Daresburg 1968, pp. 280 - 291

[3] Bergere, R., Veyssiere, A. and Doujat, P.: Rev. Sci.Instr. 33 (1962) pp. 1441 - 1449

In figure 1 the horizontal and vertical displacement is detected by measuring the difference of the induced signals:

$R_{HOR,1} = A - B$ (A, B, C, D: induced signals to the loops a, b, c, d) (1)

$R_{VERT,1} = C - D$

In figure 2 the measured displacement is:

$R_{HOR,2} = E + F - G - H$ (E, F, G, H: induced signals to the loops e, f, g, h) (2)

$R_{VERT,2} = E + G - F - H$

As shown later, both configurations give distorted response. With a 8-loop-monitor, that is a combination of both 4-loop-monitors, one exspects a reduction of distortion because the distorsion of configuration fig. 1 is negative, the distorsion of fig. 2 on the contrary is positive.

The horizontal and vertical response is given by summarizing the responses of the 4 loop-monitors:

$R_{HOR,3} = A + E + F - B - G - H$

$R_{VERT,3} = C + E + G - D - F - H$ (3)

CALCULATION OF THE LOOP-RESPONSE:

For calculation of the induced signal to a loop the electron beam is assumed to have small expansion compared with the distance to the loop. The induction of a current to a parallel wire of length l is well known:

$$\frac{L_{12}}{A} = 2\,l\,\log\frac{l+\sqrt{r^2+l^2}}{r} - 2\sqrt{r^2+l^2} + 2\,r \qquad (4)$$

A .... constant

l .... length of the loop

r .... distance between electron-beam and loop

The distance between the electron beam and the loops can be derivated from fig. 3

$$r_1 = ((x^2+y^2)^{1/2} + 2\,(x^2+y^2)^{1/2} R \sin(\arctan(\tfrac{y}{x}) + \psi) + R^2)^{1/2}$$

$$r_2 = ((x^2+y^2)^{1/2} - 2\,(x^2+y^2)^{1/2} R \sin(\arctan(\tfrac{y}{x}) + \psi) + R^2)^{1/2}$$

$$r_3 = ((x^2+y^2)^{1/2} - 2\,(x^2+y^2)^{1/2} R \cos(\arctan(\tfrac{y}{x}) + \psi) + R^2)^{1/2} \qquad (5)$$

$$r_4 = ((x^2+y^2)^{1/2} + 2\,(x^2+y^2)^{1/2} R \cos(\arctan(\tfrac{y}{x}) + \psi) + R^2)^{1/2}$$

x, y ..... coordinates of the beam

R ..... dinstance between geometrical center and loops

ψ ..... angle between vertical-axis and loop-axis. In loop configuration fig. 1 ψ is zero and in fig. 2 ψ is $\pi/4$.

Combining the equations (4) and (5) the response for each configuration can be calculated. A rectangular lattice is constructed in the x-y plane (fig. 4). The distortion of the loop response of the lattice is demonstrated in fig. 5, 6 and 7. The indices of l and R refer to the loop-configurations of fig. 1.and 2. In table I the distortion of the different loop-configurations are compared. As to be seen from fig. 7 the lattice distances increase with increasing distances from the axis. This deviation is shown in fig. 8.

Acknowledgement:

I wish to thank Mr. H. Wiedemann for helpful discussion.

y= const (mm)	relative x - distortion between x = 1 and x = 19 mm: 4 - loop - configurations: config. fig. 1 (%)	config. fig. 2 (%)	8-loop-config.
1	- 9,9	13,3	1,0
3	- 9,0	13,3	0,96
5	- 9,1	13,4	0,97
7	- 9,1	13,6	0,98
9	- 9,2	13,8	1,0
11	- 9,4	14,1	1,0
13	- 9,5	14,5	1,0
15	- 9,7	14,9	1,1
17	- 9,9	15,4	1,0
19	- 10,1	16,0	1,1
21	- 10,4	16,6	1,0
23	- 10,7	17,3	1,0
25	- 11,1	18,0	0,93
27	- 11,5	18,7	0,8
29	- 12,0	19,4	0,62
31	- 12,5	20,2	0,38
33	- 13,1	20,9	0,06
35	- 13,7	21,6	- 0,36
37	- 14,4	22,3	- 0,89
39	- 15,2	22,8	- 1,6
41	- 16,1	23,3	- 2,4
43	- 17,1	23,7	- 3,3
45	- 18,2	23,9	- 4,5
47	- 19,4	24,0	- 5,8
49	- 20,8	24,0	- 7,3

Table 1: Relative distortion of 4-loop- and 8-loop-monitors

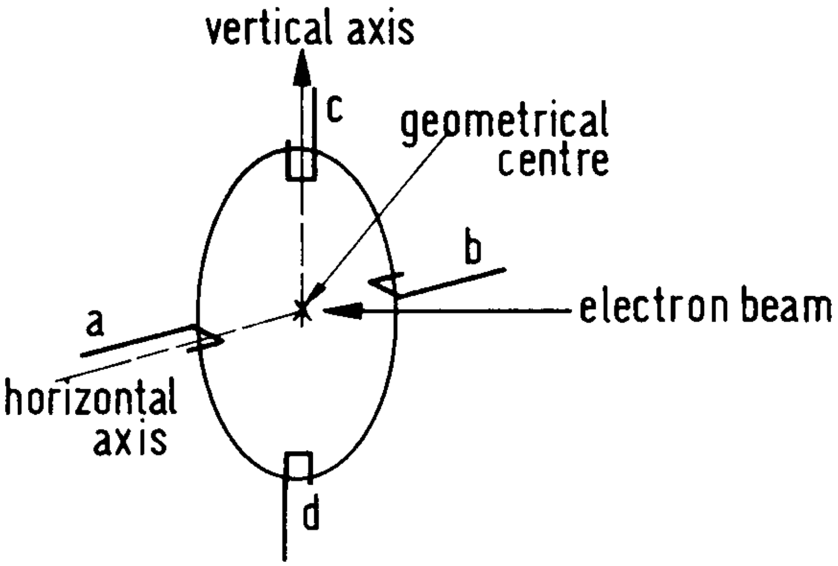

Fig. 1 4-Loop-Monitor. The loops are situated in the horizontal and vertical planes

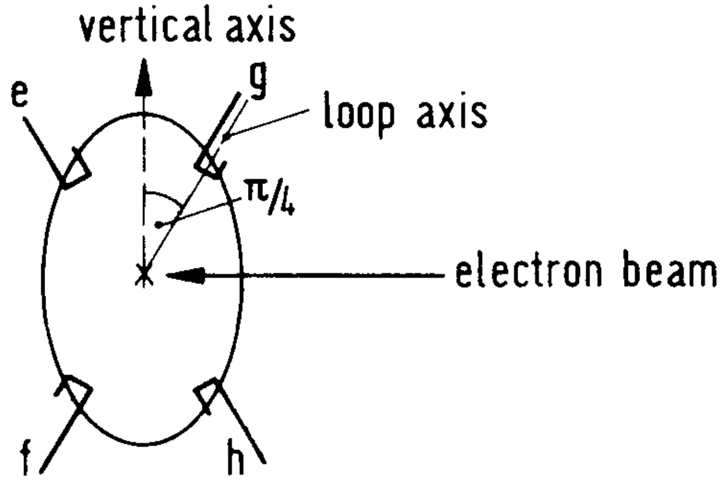

Fig. 2 4-Loop-Monitor. The loops are shifted by 45° compared to Fig. 1

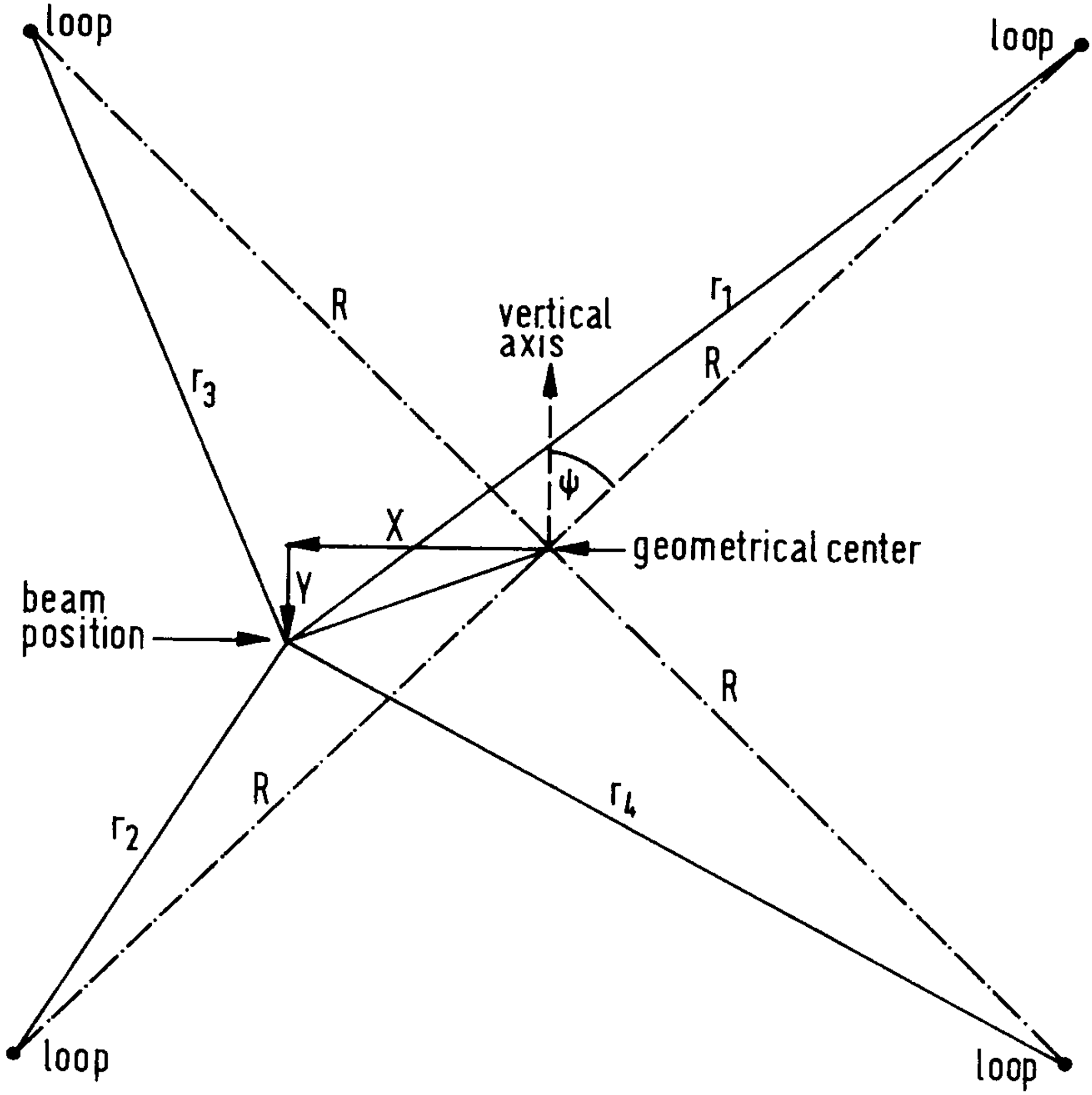

Fig. 3 Beam position and geometrical center with 4 loop configuration

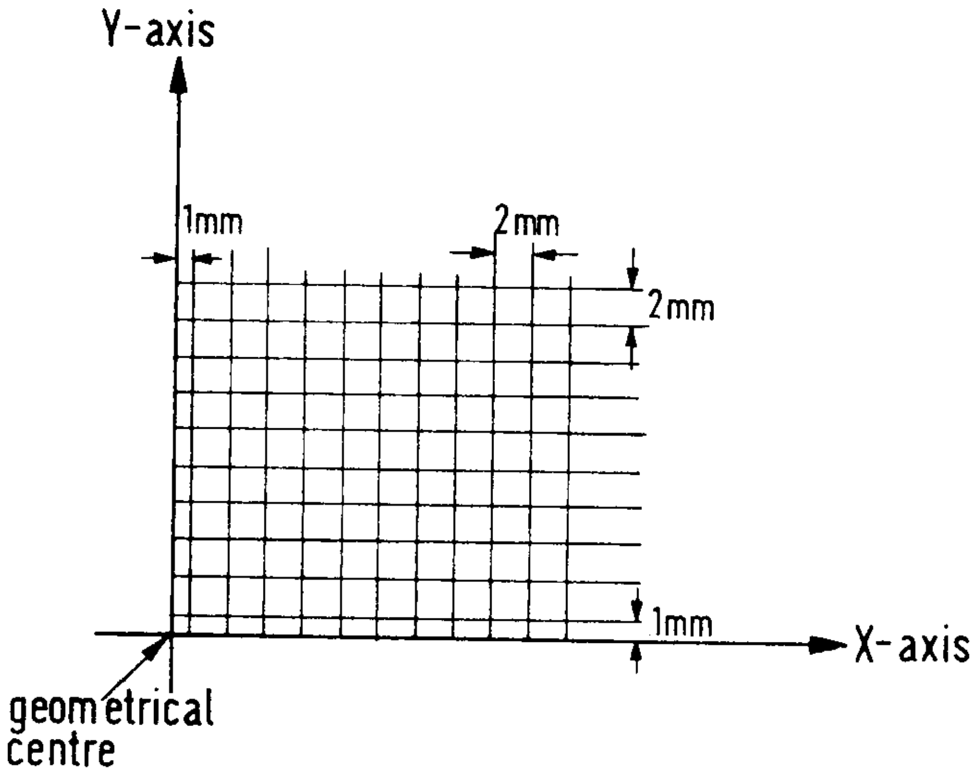

Fig.4 Rectangular lattice in x-y plane (on quarter of the total plane)

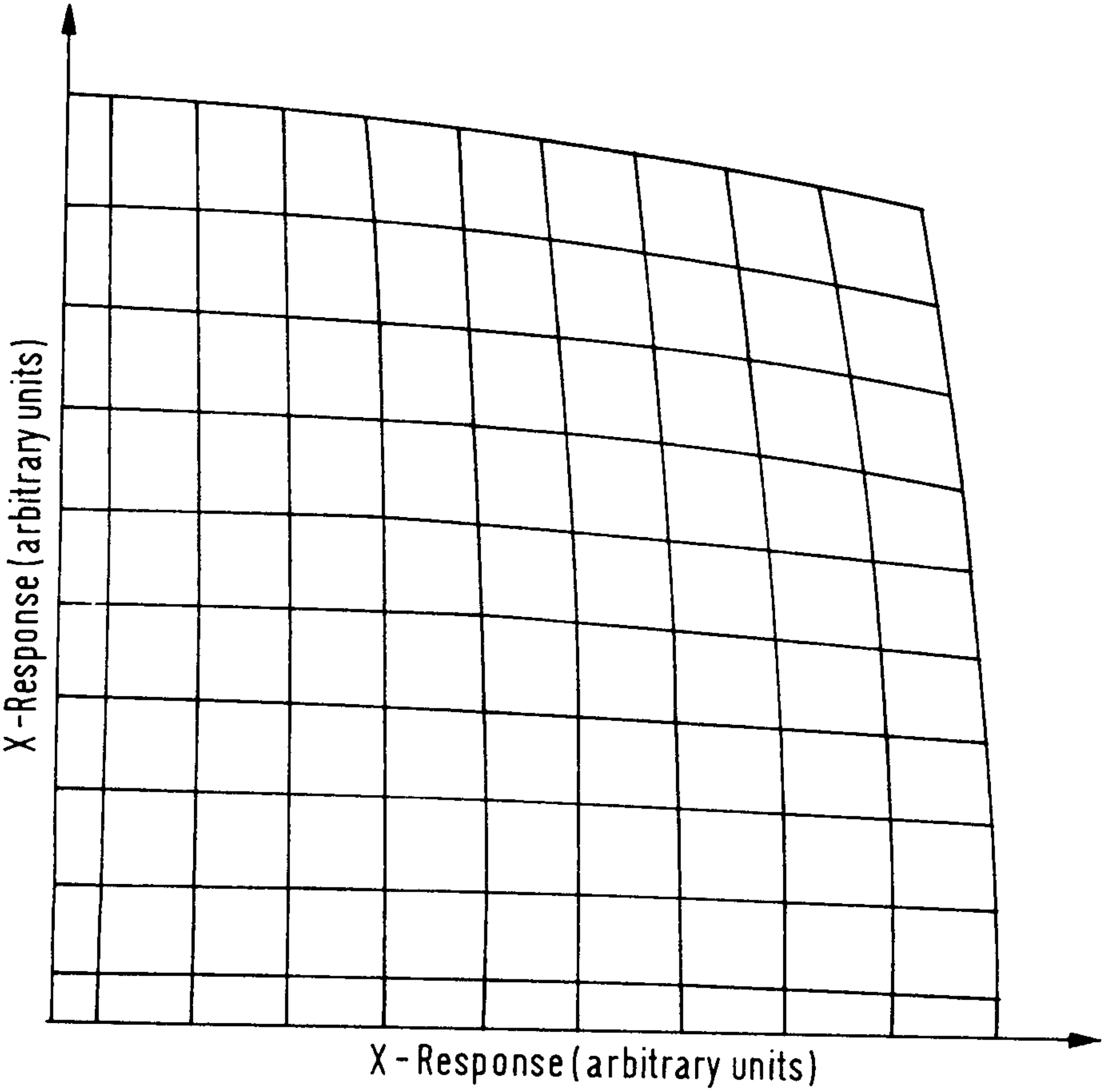

Fig.5 Response of the rectangular lattice Fig.4 produced by a loop configuration according to Fig.1 (R_1 = 72 mm, l_1 = 28 mm)

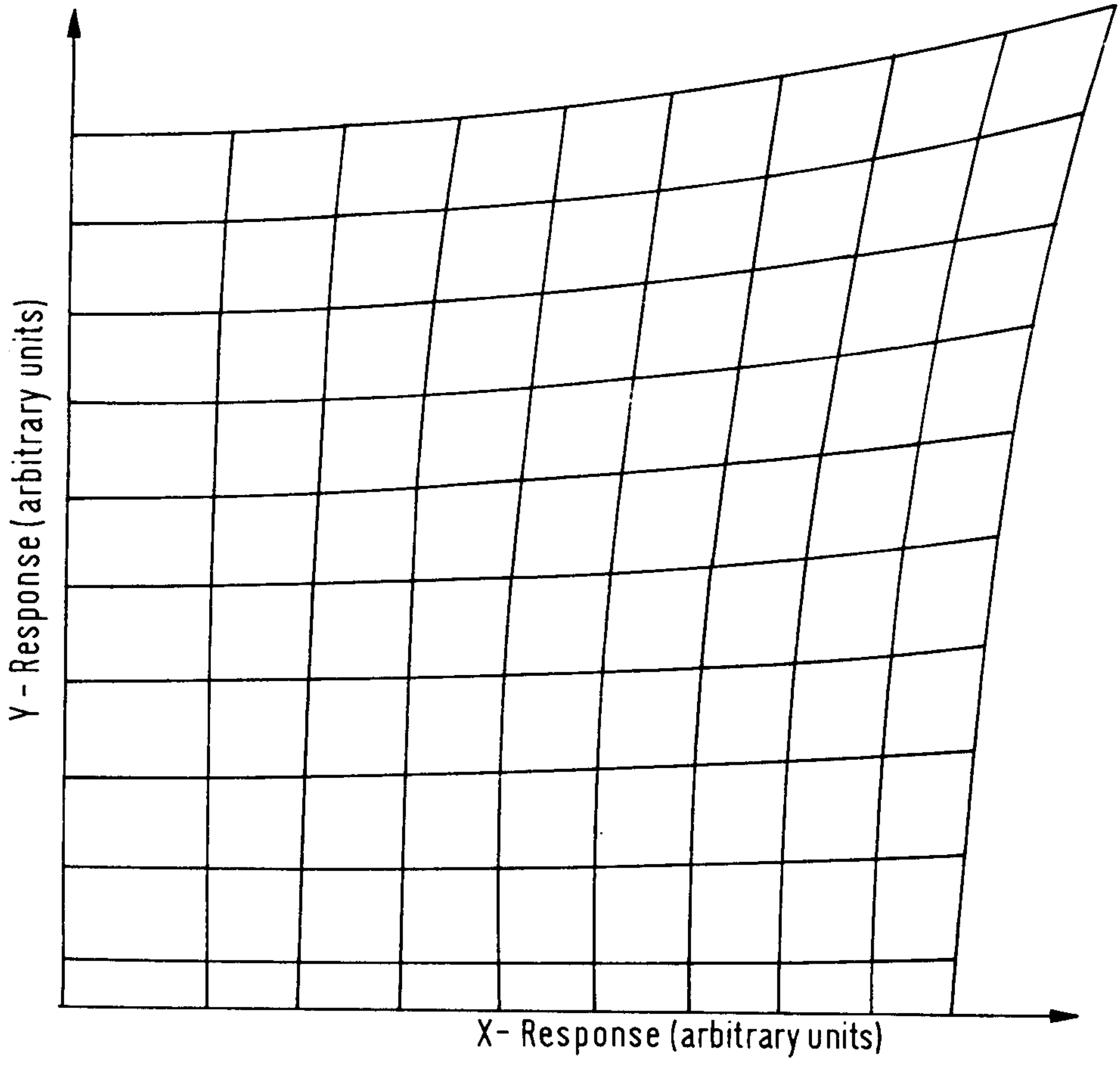

Fig.6 Response of the rectangular lattice Fig.4 produced by a loop configuration according to Fig. 2 ($R_2 = 72$ mm, $l_2 = 21$ mm)

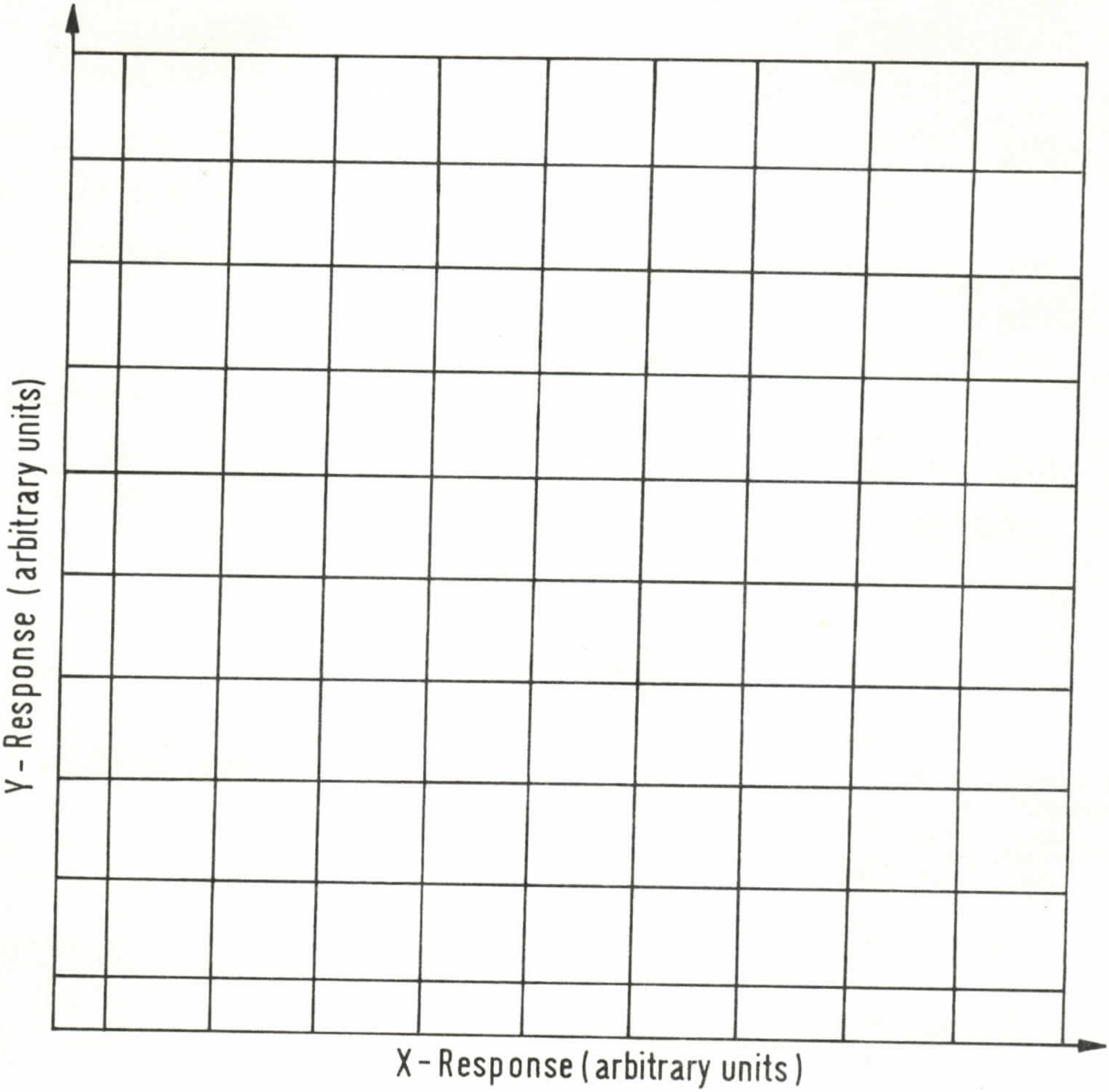

Fig. 7 Response of the rectangular lattice Fig. 4 produced by a 8 loop monitor
(R_1 = 72 mm, R_2 = 72 mm; l_1 = 28 mm; l_2 = 21 mm)

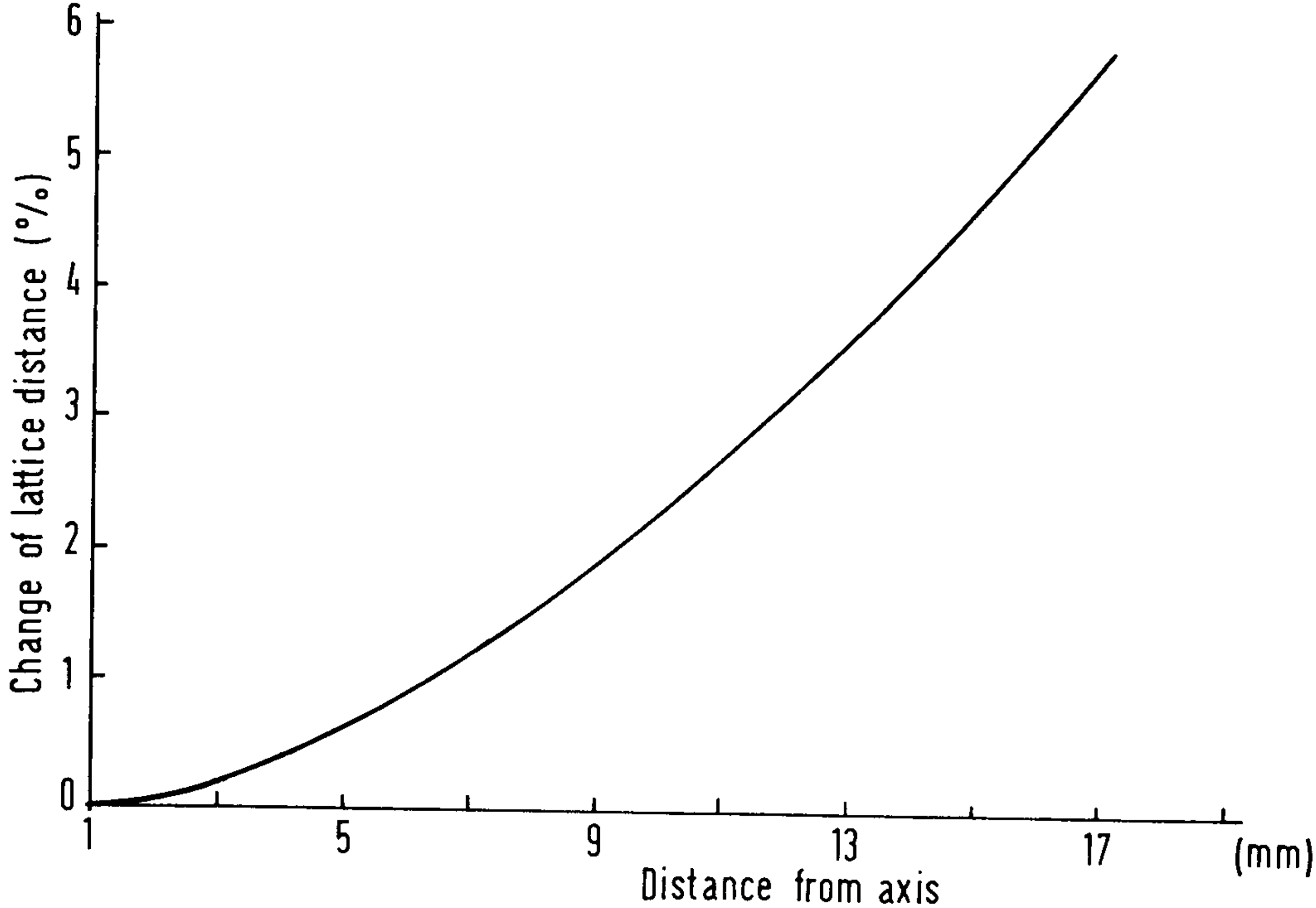

Fig.8 Lattice distance versus distance from axis (8 loop monitor)