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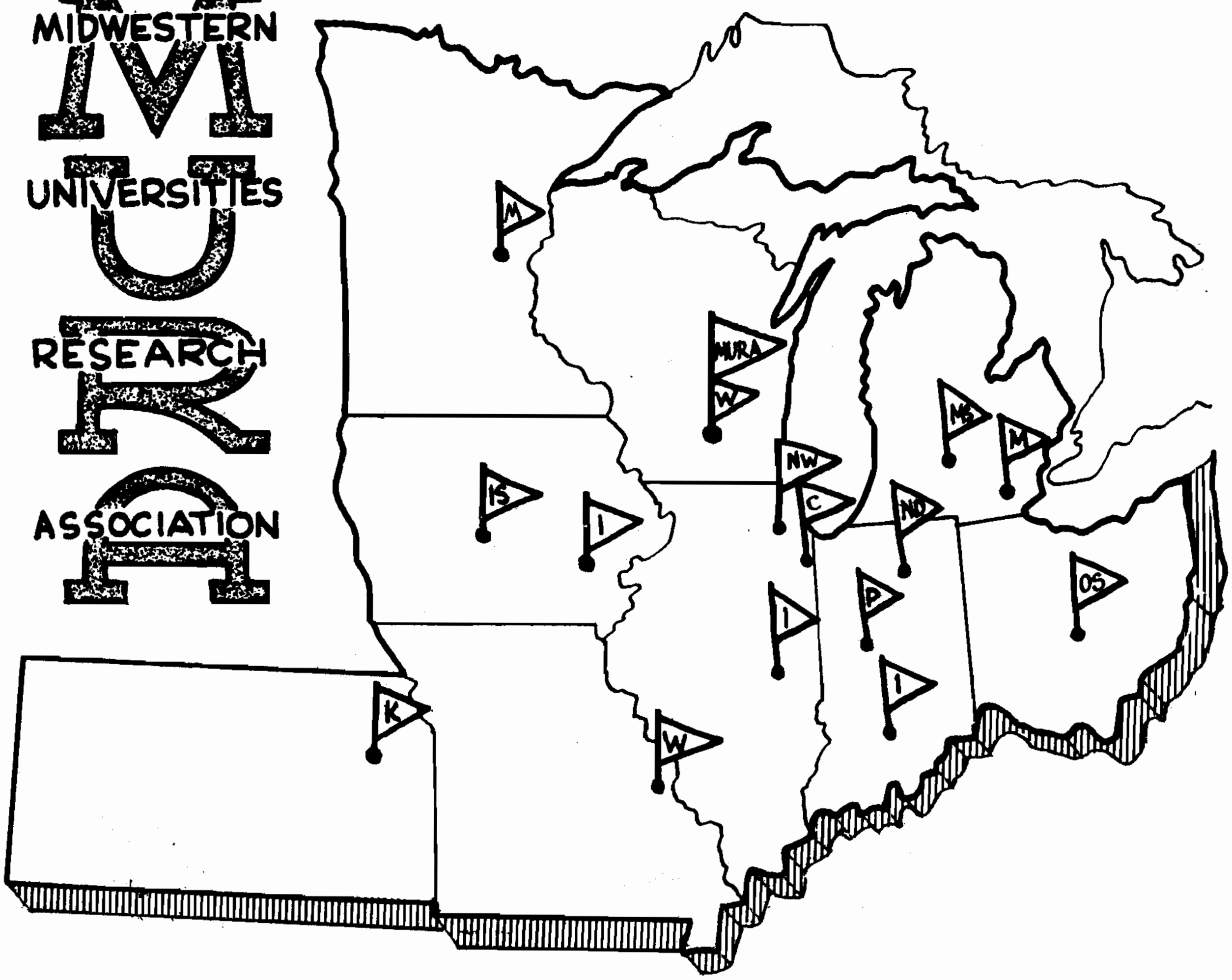

FREQUENCY MEASUREMENTS AND RESONANCE SURVEY IN THE ELECTRON MODEL SPIRAL SECTOR FFAG ACCELERATOR

R. Stump and B. Waldman

REPORT NUMBER 361

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FREQUENCY MEASUREMENTS AND RESONANCE SURVEY IN THE ELECTRON MODEL SPIRAL SECTOR FFAG ACCELERATOR

R. Stump** and B. Waldman***

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ABSTRACT

Beam intensities, vertical and radial betatron oscillation frequencies, and stop bands in the tuning range of the spiral sector FFAG accelerator were measured. The machine is tunable from $\nu_z = 0.46$ to 1.76 and $\nu_x = 1.12$ to 1.71. In this tuning region the resonances $\nu_z = 1$, $\nu_z = 0.5$, $\nu_z = 1.5$, $\nu_x = 1.5$, $\nu_x + \nu_z = 2$ and $2\nu_x + 2\nu_z = 6$ are observed to destroy the beam. Of these only $\nu_z = 1$, $\nu_z = 0.5$ and $2\nu_x + 2\nu_z = 6$ cause complete loss of beam at all points in the available tuning range. The Walkinshaw resonance $(2\nu_z - \nu_x = 0)$ appears as a minimum of beam intensity.

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Introduction

This report describes a series of measurements which were made on the electron model spiral sector FFAG accelerator, to determine the tuning characteristics of this machine. Beam intensities, vertical and radial betatron oscillation frequencies, and stop bands in the tuning range available were found.

Experimental Arrangement

1) Detector

A cylindrical plastic scintillator of 1 cm diameter and 1 cm length was mounted at the end of a light pipe inside the vacuum donut. A thin layer of aluminum was evaporated over the scintillation to make it light tight and still allow the electrons to enter. The photomultiplier was outside of the magnetic field. The presence of an electron beam was detected by observing a pulse on an oscilloscope at the proper time after injection.

2) RF Probe

Betatron frequencies were determined by the rf. knock-out method described by Cole et al (RSI, 28, 403 (1957)). The probe consisted of two parallel plates inserted approximately at the beam position in the donut. One plate was grounded, the other had an rf. voltage of approximately 50 volts. Resonance with the radial betatron frequency was identified by the shift of the time of arrival of the beam. Vertical betatron frequency was identified by a decrease of intensity. Resonances identified were usually of the form:

$$f_{rf}/f_o = |a\nu - n|$$

where f_o is the frequency of revolution of the electron, f_{rf} is the applied rf. frequency, a is 1 or 2, and n is zero or any integer.

Radio frequencies were measured with a grid dip meter and could be reproduced to about 1%.

3) Tuning Parameters

The current through the flutter ($\triangle$F) coils could be varied from zero to $\pm$ 1.5 amperes. Likewise the current in the Δk coils could be varied from zero to $\pm$ 1.33 amperes.

Results

The betatron frequencies, ν_x and ν_z, were measured at the radius of 42.5 cm, over the complete range of tuning. The results are plotted in Fig. 1 and Fig. 2.

The tuning regions where a beam was not obtained were identified in terms of the parameters ΔF and Δk. Fig. 3 illustrates these data. Beam intensity varied with inflector and injector voltage. These were adjusted to give maximum beam when determining regions of beam extinction. All magnetic fields were recycled in these regions to eliminate hysteresis effects.

With the data of Fig. 1 and Fig. 2 a cross plot of Fig. 3 was made. This is shown in Fig. 4. Certain resonances are entered on this plot.

Intensities were estimated by the amplitude of the pulse from the photomultiplier. Where no beam is indicated the intensity was less than 10^{-3} times the intensity found in neighboring regions. Where minima are indicated (Fig. 4), the intensity dropped to 10^{-1} to 10^{-2} times the normal beam intensity.

Examination of Fig. 4 shows that the integral resonance $\nu_z = 1$, the half-integral resonances $\nu_z = 0.5$, $\nu_z = 1.5$, $\nu_x = 1.5$ and the linear sum resonances $\nu_x + \nu_z = 2$ and $2\nu_x + 2\nu_z = 6$ (which is also a cubic resonance $2\sigma_x + 2\sigma_z = 2\pi$) all destroy the beam completely at some tuning. Of these only $\nu_z = 1$, $\nu_z = 0.5$ and $2\nu_x + 2\nu_z = 6$ cause complete loss of the beam at all points in the tuning region. Beam was found in some regions of half-integral resonance. In these regions there was however a marked decrease of intensity. These regions were carefully examined to determine both that the beam existed and that the frequencies actually crossed the resonances. The Walkinshaw resonance ($\nu_x - 2\nu_z = 0$) appeared as a minimum, but did not destroy the beam completely. The $2\nu_x + 2\nu_z = 6$ resonance appears to have the wrong slope. This is possibly due to the lack of scaling in the machine, together with the possibility that this resonance is serious only near injection.

APPENDIX

Parameters of the Electron Model Spiral Sector FFAG Accelerator

$N = 6$	R_o = 55 cm. (Outer radius)
$\frac{1}{w} = 6.25$	E_{inj} = 25 kev (Injection Energy)
$k = 0.7$	Design Flutter = 1.08
R_i = 30.5 cm. (Inner radius)	Measured Flutter = 1.02

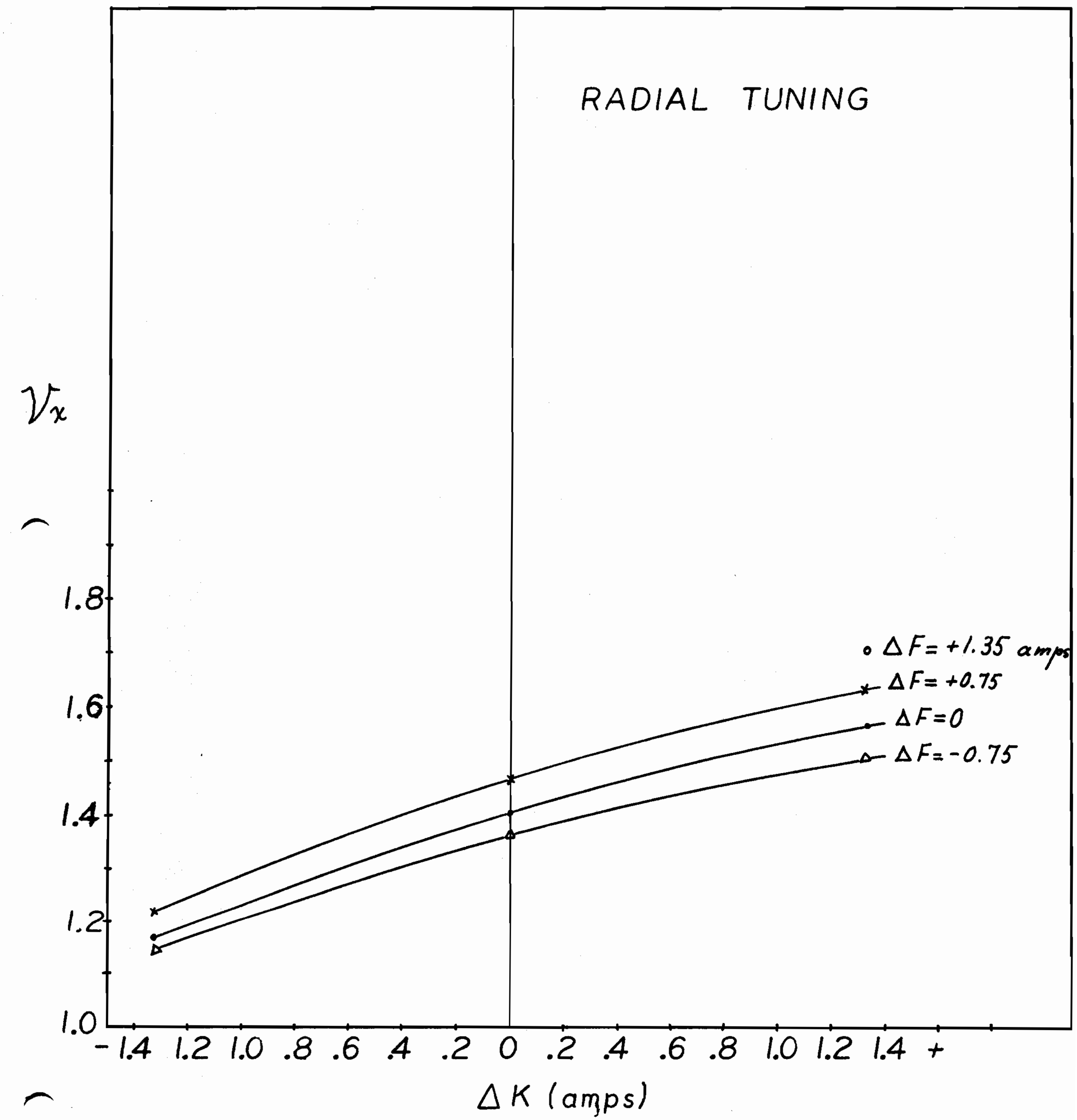
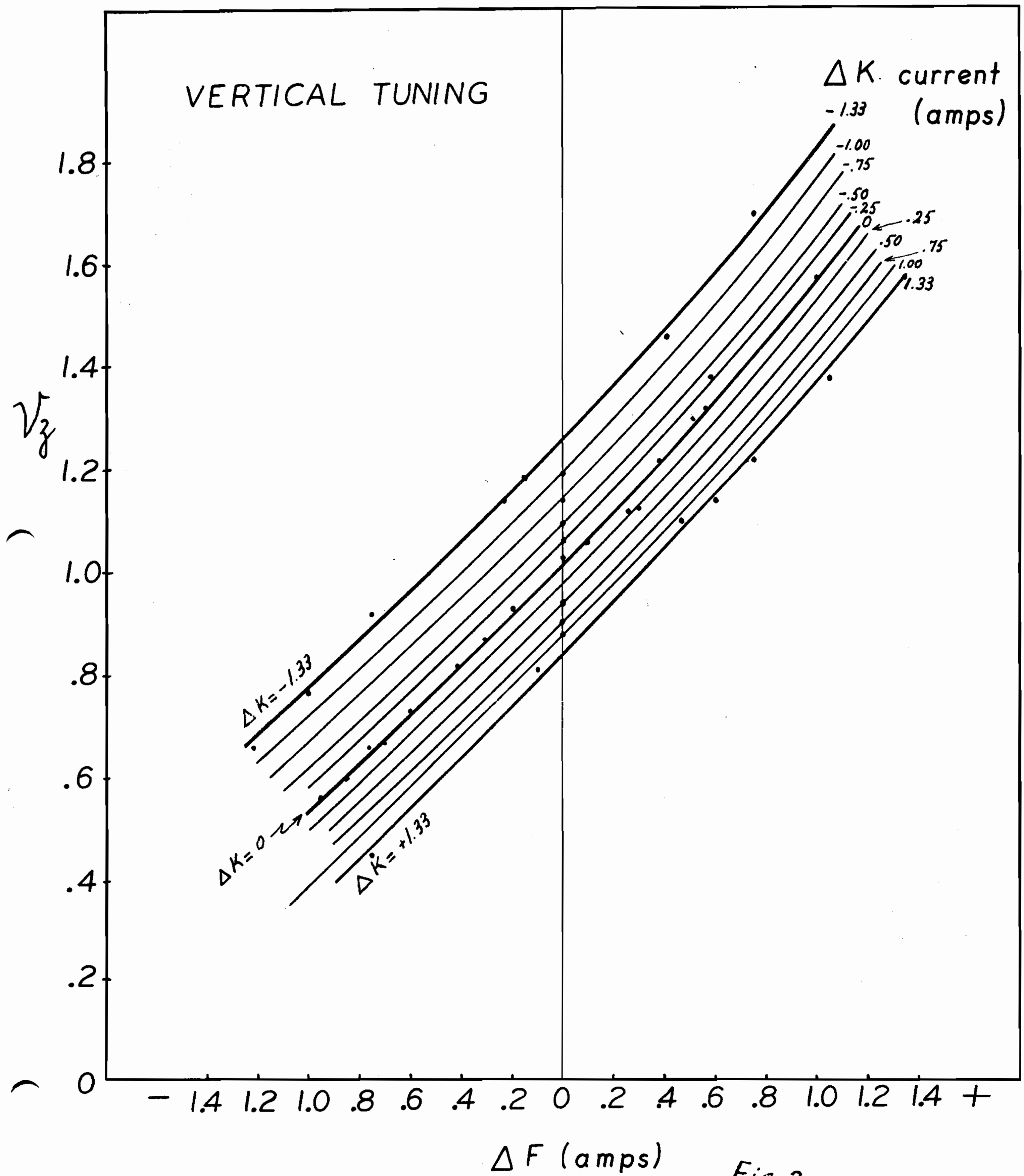
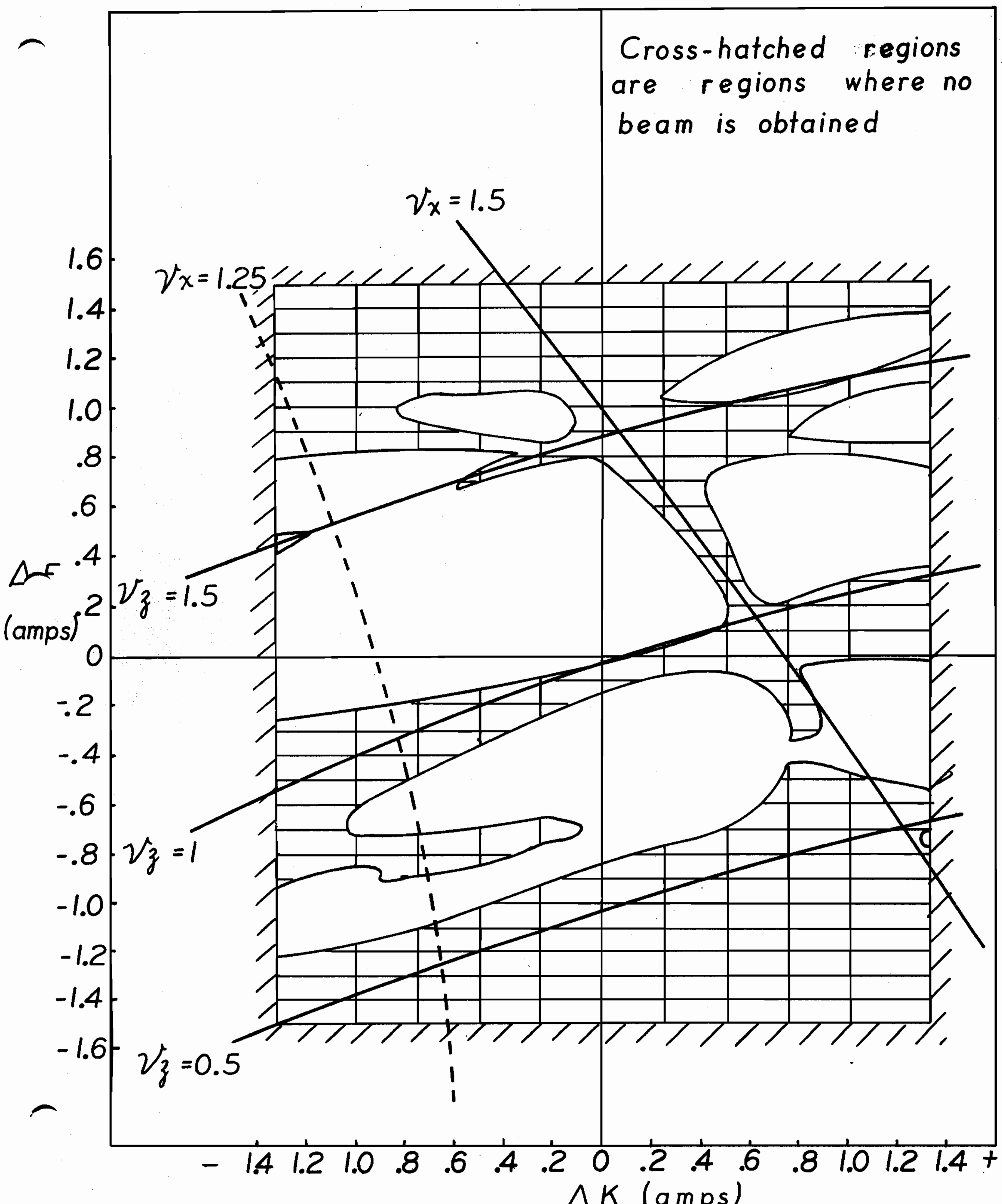

RADIAL TUNING
ν_x
1.8
1.6
1.4
1.2
1.0
∘ ΔF = +1.35 amps
ΔF = +0.75
ΔF = 0
ΔF = -0.75
- 1.4 1.2 1.0 .8 .6 .4 .2 0 .2 .4 .6 .8 1.0 1.2 1.4 +
ΔK (amps)

Fig. 1



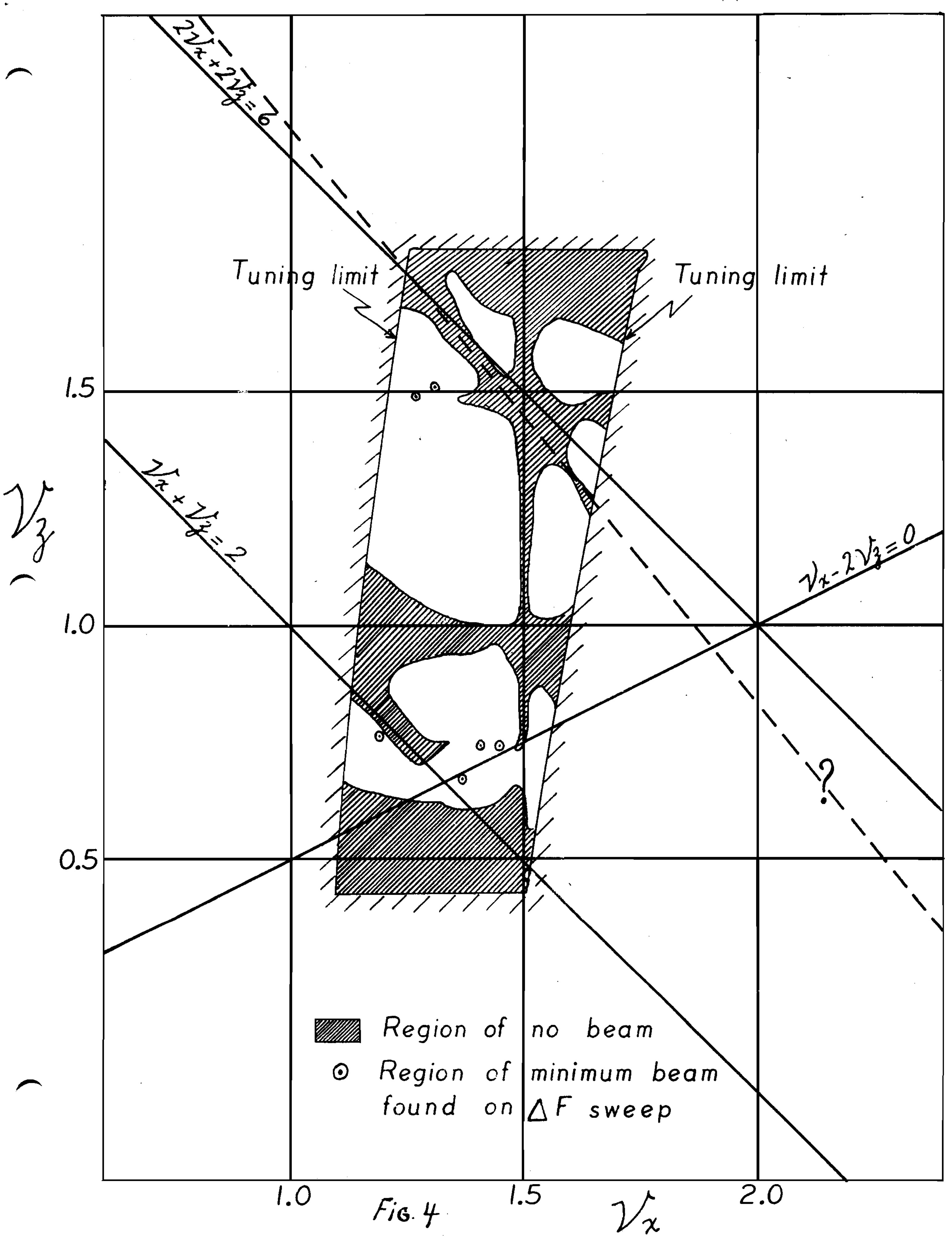
VERTICAL TUNING
ΔK current (amps)
- 1.33
-1.00
-.75
-.50
-.25
0
.25
.50
.75
1.00
1.33
ΔK=-1.33
ΔK=0
ΔK=+1.33
ν_z
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
− 1.4 1.2 1.0 .8 .6 .4 .2 0 .2 .4 .6 .8 1.0 1.2 1.4 +
ΔF (amps)

Fig. 2



Cross-hatched regions are regions where no beam is obtained
νx = 1.5
νx = 1.25
νz = 1.5
νz = 1
νz = 0.5
ΔF (amps)
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
-1.4
-1.6
– 1.4 1.2 1.0 .8 .6 .4 .2 0 .2 .4 .6 .8 1.0 1.2 1.4 +
ΔK (amps)

Fig. 3



$2\nu_x + 2\nu_z = 6$
Tuning limit
Tuning limit
$\nu_x + \nu_z = 2$
$\nu_x - 2\nu_z = 0$
?
ν_z
1.5
1.0
0.5
1.0
1.5
2.0
ν_x
Region of no beam
Region of minimum beam found on ΔF sweep

Fig. 4

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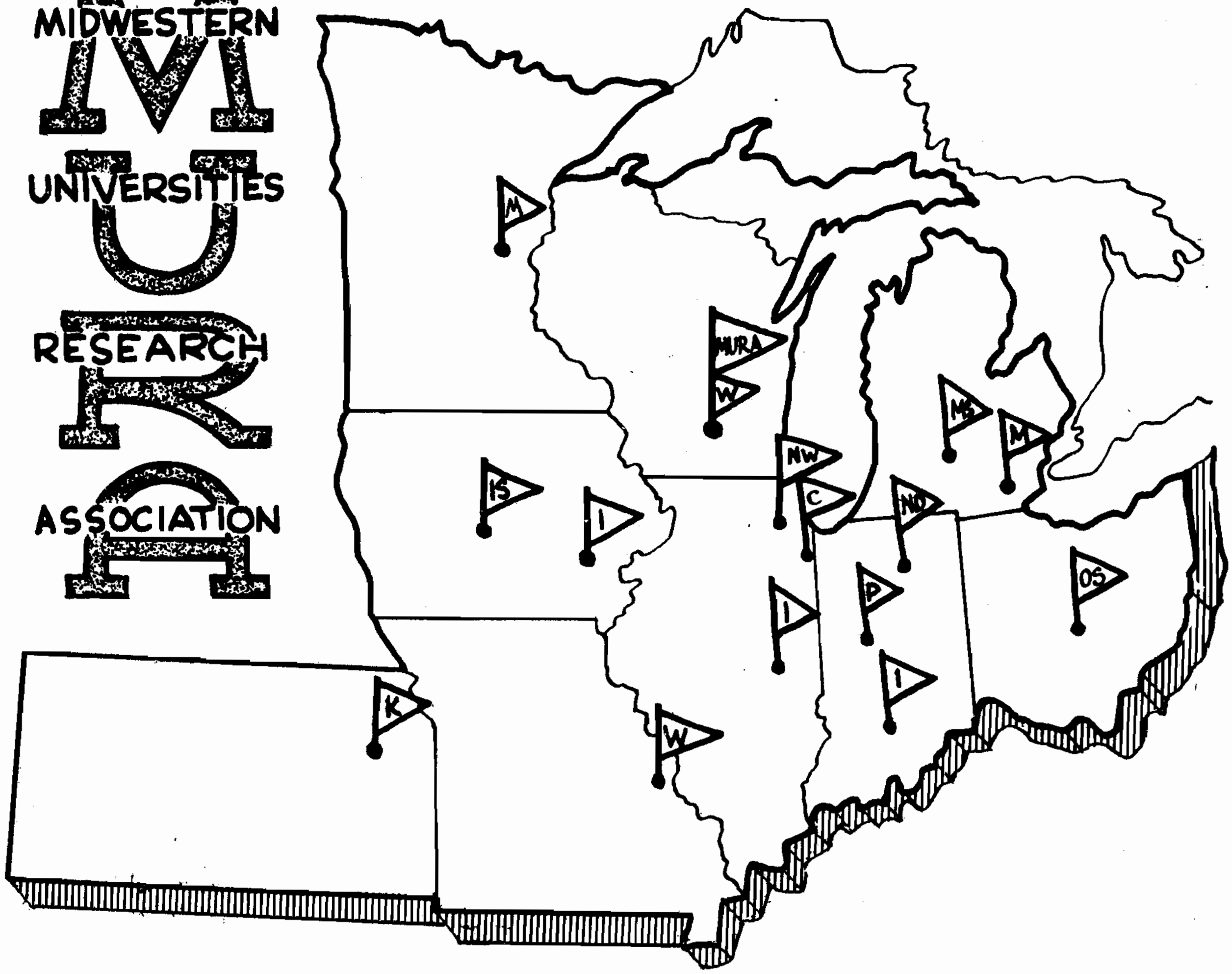

THE $\nu = \frac{1}{3} N$ NON-LINEAR RESONANCE OF A

FIXED FIELD ACCELERATOR

G. Parzen

REPORT NUMBER 362

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THE $\nu = \frac{1}{3} N$ NON-LINEAR RESONANCE OF A FIXED FIELD ACCELERATOR

G. Parzen**

June 8, 1957

ABSTRACT

This paper is a continuation of the reports MURA-258, and MURA-273. This paper treats the problem of finding the stability limits, due to the $\nu = \frac{1}{3} N$ non-linear resonance in the radial motion, of an accelerator having an arbitrary magnetic field. The general spiral sector machine is treated in detail. The results of the theory are compared with numerically computed results.

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** On leave from the University of Notre Dame