Bunch Feedback Systems

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- Introduction
- Pickup-part
- Signal Process Part
- Kicker part

Main machine parameters of KEKB

Ring name	LER	HER
Energy (GeV)	3.5	8.0
Circumference (m)	~ 3016	
Harmonic number	5120 $= 2^{10} \times 5$	
# of particles/bunch	3.3×10^{10}	1.4×10^{10}
# of bunches	~ 5000	
Bunch frequency (MHz)	~ 508.9	
Momentum compaction	~ 0.015	
Bunch length (cm)	~ 0.5	

Required damping times

- Source of the instabilities

  longitudinal: - HOMs of the cavities
  - the fundamental mode of the cavities (auxiliary)

  transverese: - HOMs of the cavities
  - resistive wall
  - beam-ion instabilities
  - beam-electron instabilities

- required damping times

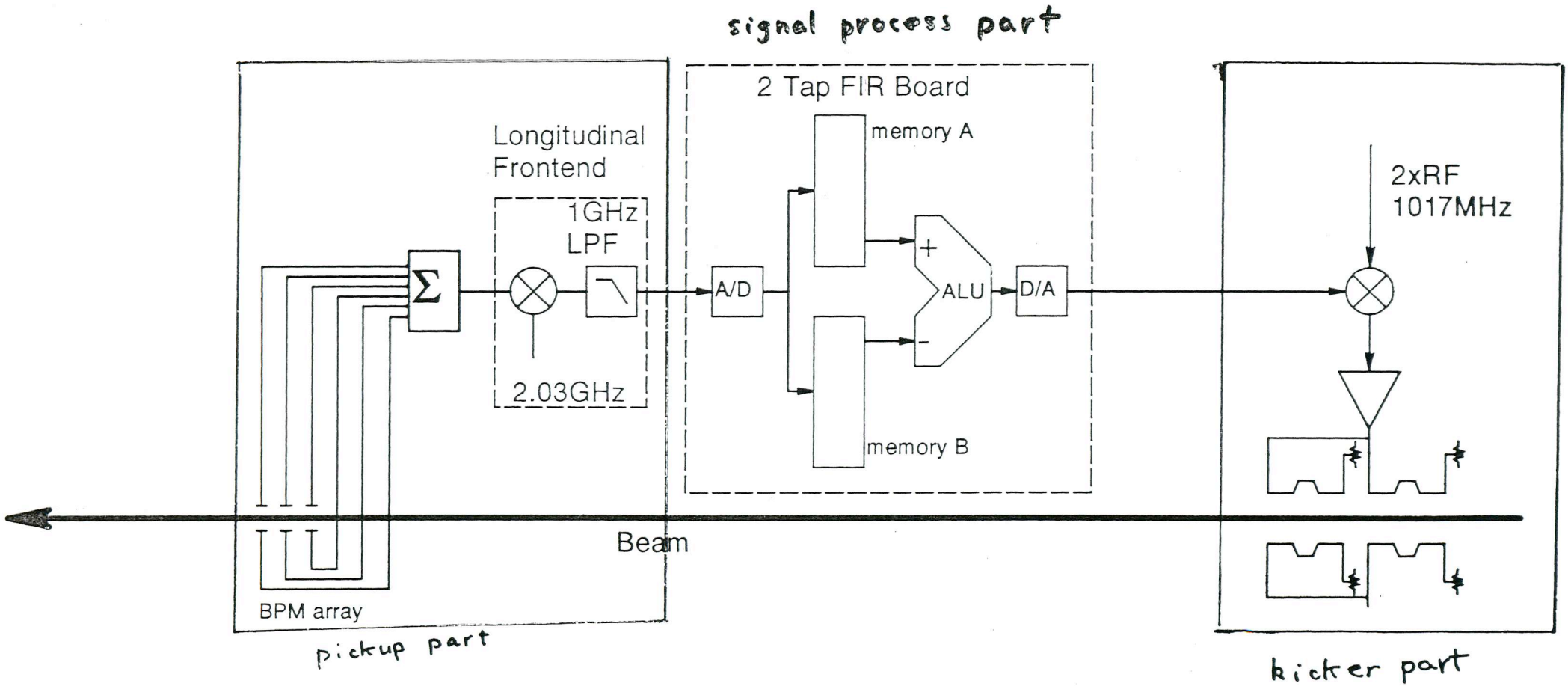
longitudinal	10 ms
transverse	1 ms

Main Features of
KEKB Bunch Feedback Systems

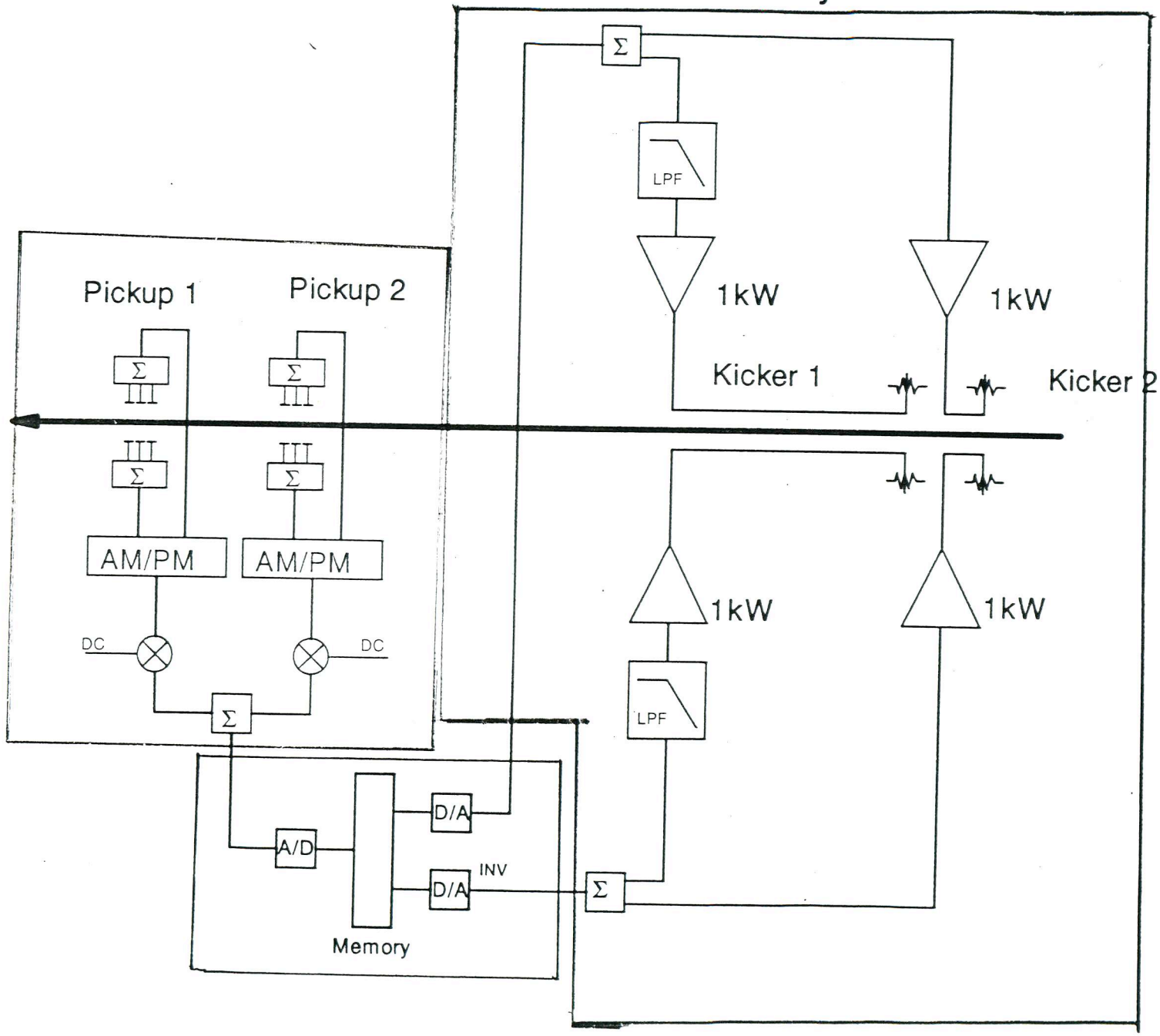
- Bunch by bunch feedback system
  it can deal with various type of oscillations
  with
  2 ns-separable pickup
  wide band kickers ~250MHz

- Digital signal process
  with
  8 bit A-to-D converter / D to A converter
  custom LSI for de-multiplexing / multiplexing
  pure hardware logic (for 2-tap filter)

Longitudinal Bunch Feedback System



Transverse Bunch Feedback System



Pickup Part

- Electrode type --> button

  a train of button electrodes will be used

- Frontend electronics

  pickup signal -------> sine-like signals

  of ~ 2 GHz (RF freq. x 4)

  — longitudinal

  simple phase comparing

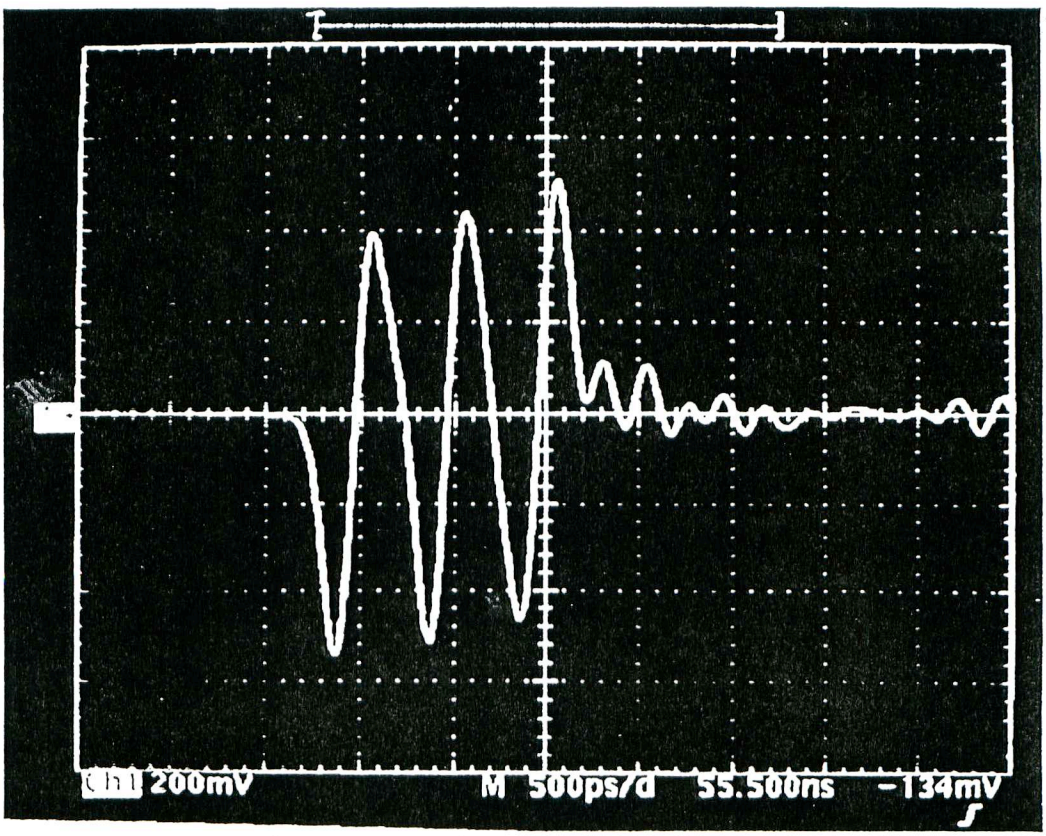
  standard timing signal
  pickup sine-like signal

  — transverse (AM/PM)

  amplitude difference of pair of the sine-like signals

  is converted to

  the phase difference of two sine-like signals

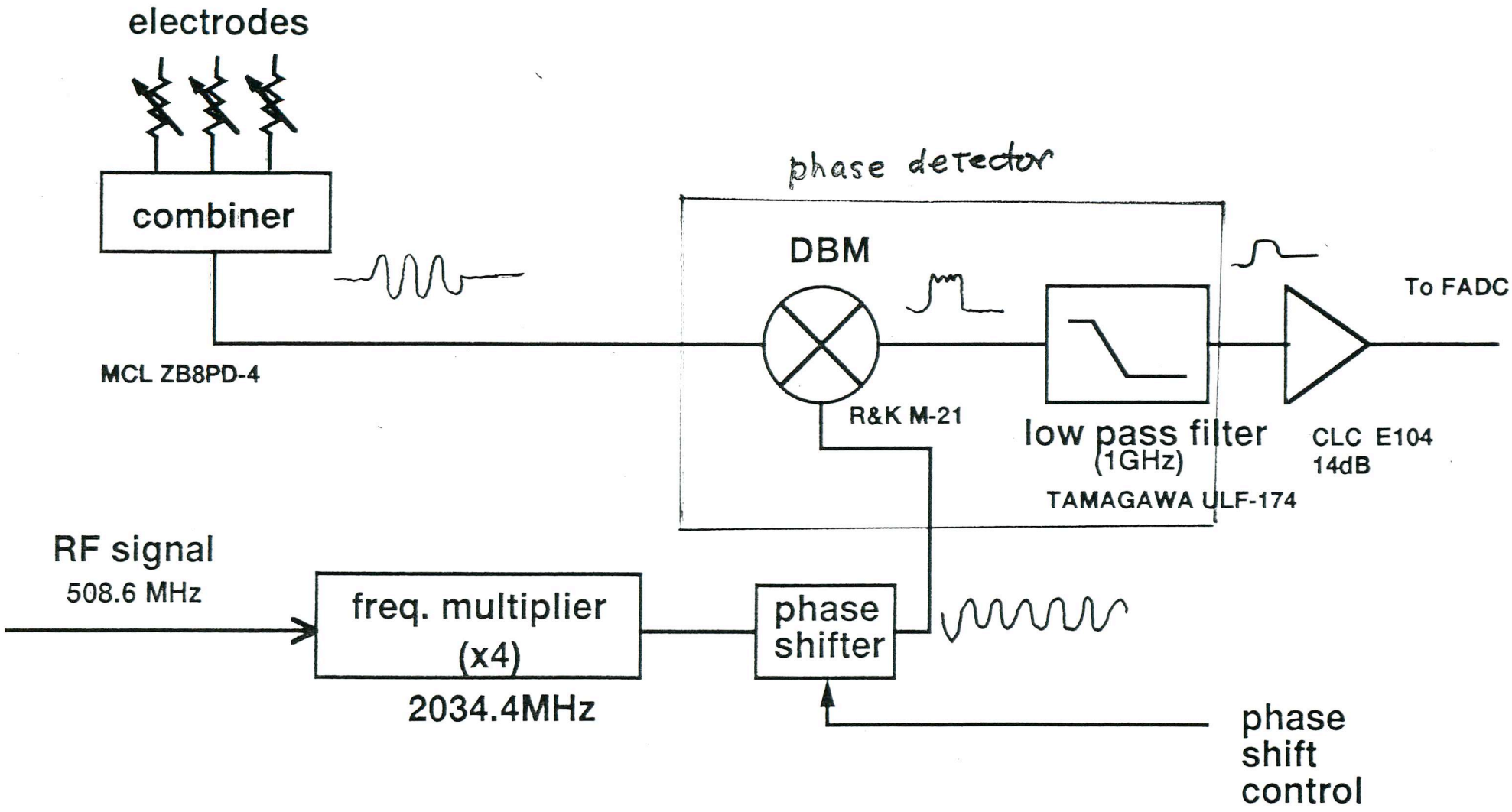


2ns

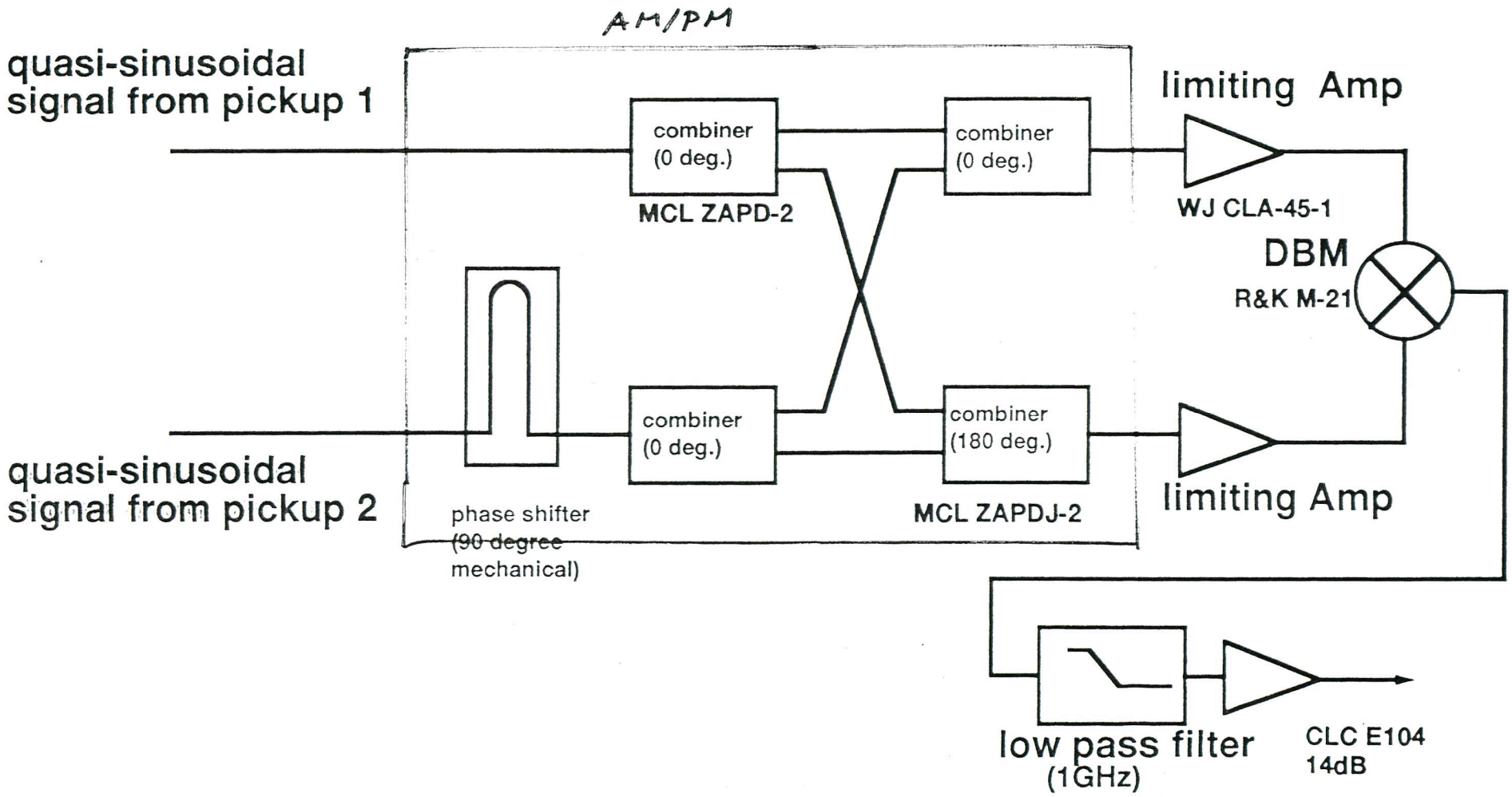
The sine-like signal

(AR experiment)

The pulse train is held in 2 ns.



Block Diagram of the Front-End Circuit (long.)



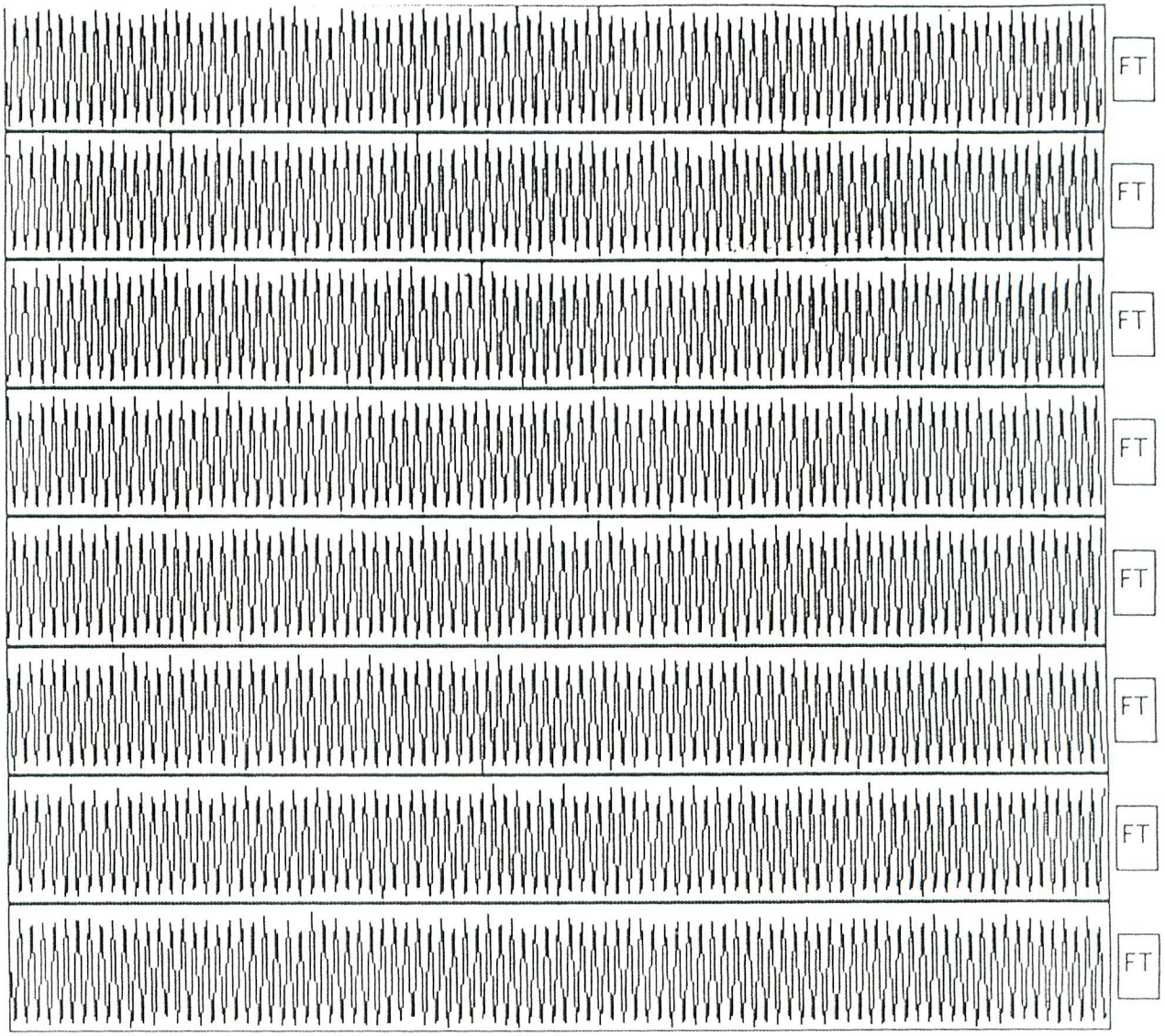
Front-end Circuit (Transverse)

KEKB

Max=234
min= 78
<x1>=164.178
S1=50.045
<x2>=164.178
S2=50.045
N=4096

AR0008.adc

Exit

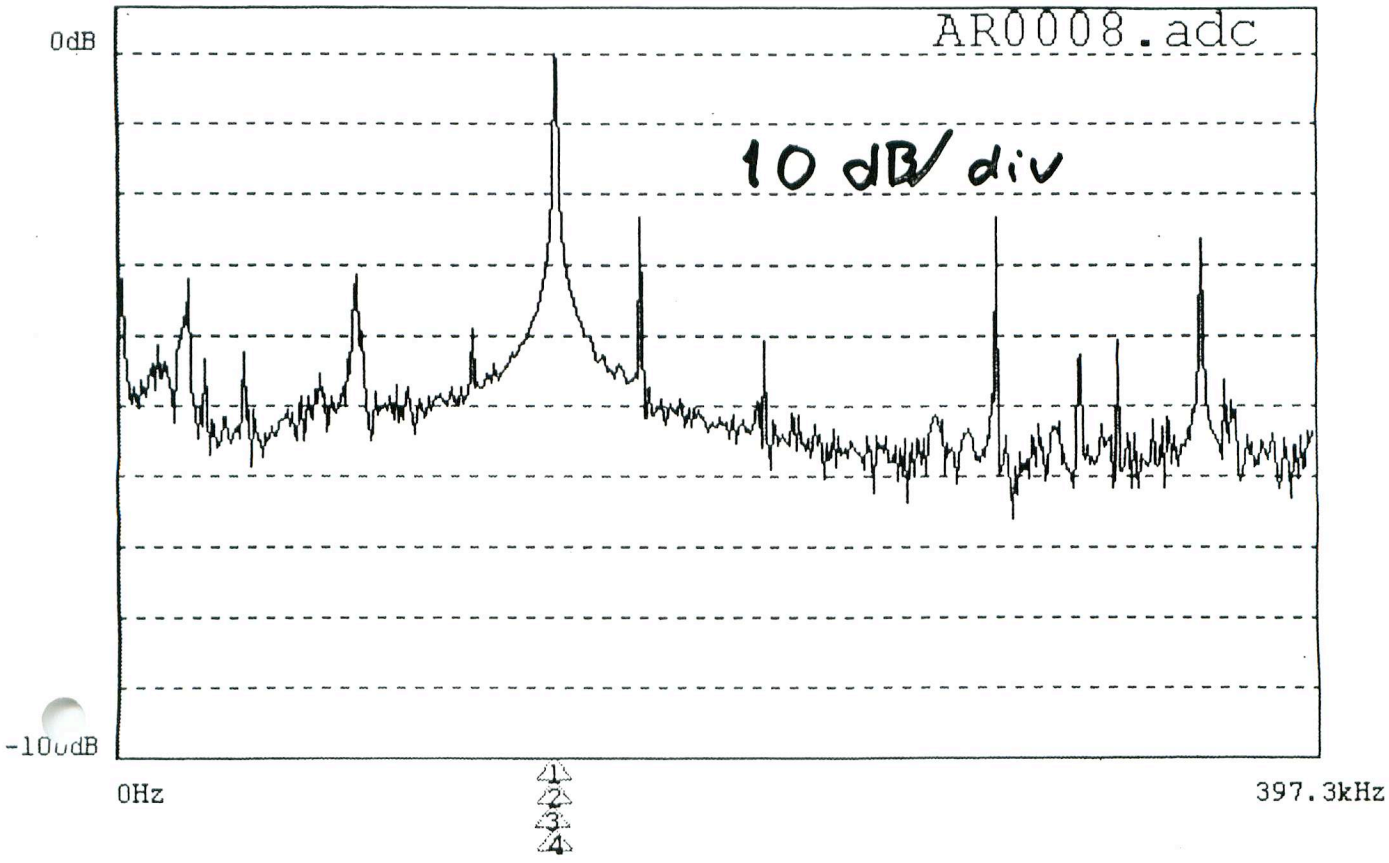


4096 turns

transuerse oscillation obserued in AR..

Oscillation was excited artificilly.

Data was taken by 8-bit A to D.



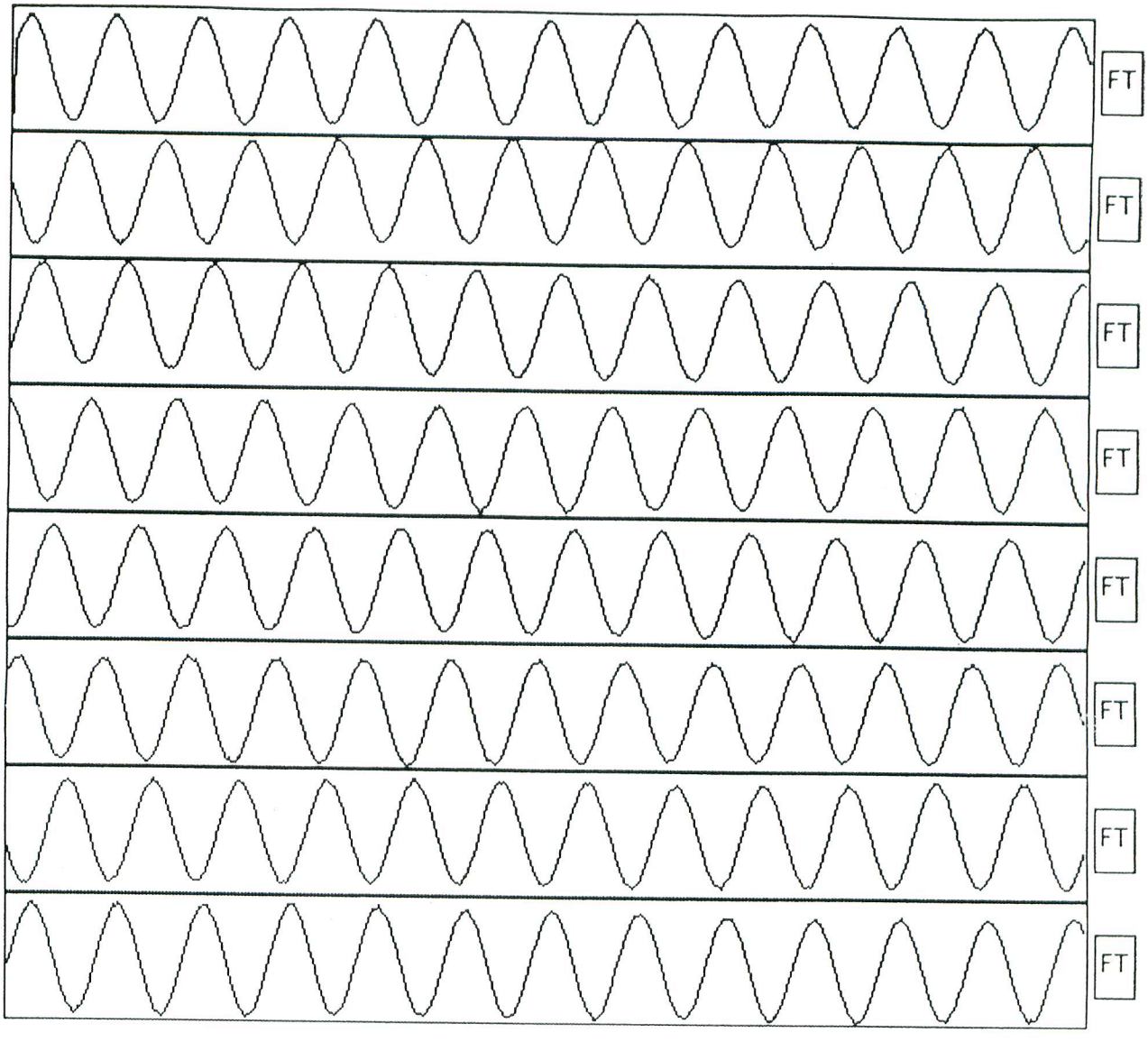
FFT analysis of transverse oscillation

The signal is higher than the background by ~ 50 dB

Max=239
min= 32
<x1>=137.739
S1=61.929
<x2>=137.739
S2=61.929
N=4096

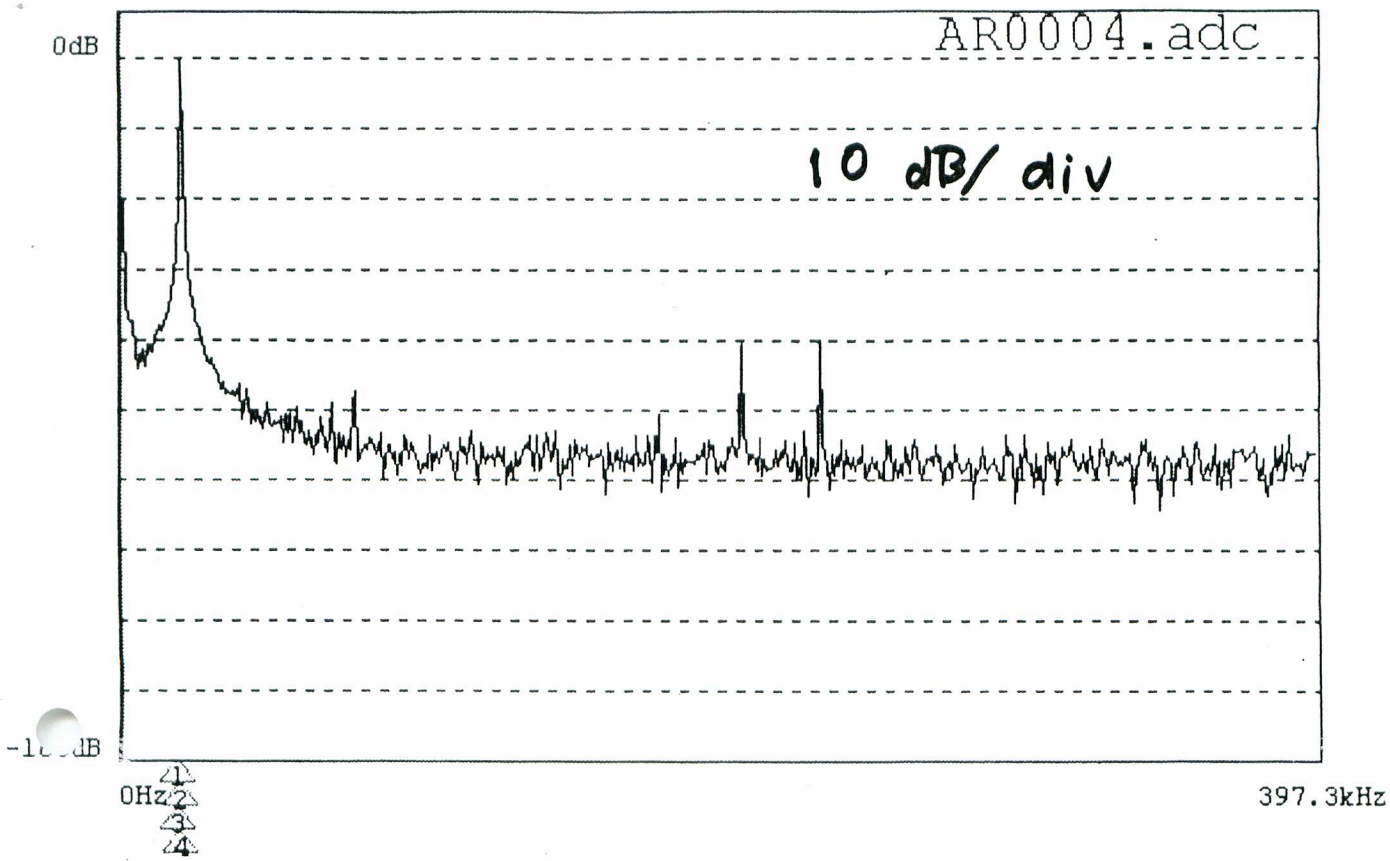
AR0004.adc

Exit



Longitudinal oscillation observed in AR.

The oscillation was artificially excited by shaking the phase of RF cavities.



19.21kHz---> 0.00dB
19.40kHz---> -6.67dB
19.01kHz---> -12.13dB
19.60kHz---> -14.66dB
18.82kHz---> -16.94dB
19.79kHz---> -18.31dB
18.63kHz---> -19.65dB

End SW

FFT analysis of longitudinal oscillation

Signal is higher than the background by ~ 50 dB

Signal Process Part
(digital system)

- 1-turn delay

- DC-suppress and phase adjustment
  (longitudinal)

These are done by a very simple digital filter (2-tap filter)
In general, the function of *Finite Impulse Response filter* is expressed by

$$y = \sum_{i=0}^{M-1} a_i x_i$$

y : output
x_i : inputs
a_i : filter coefficients

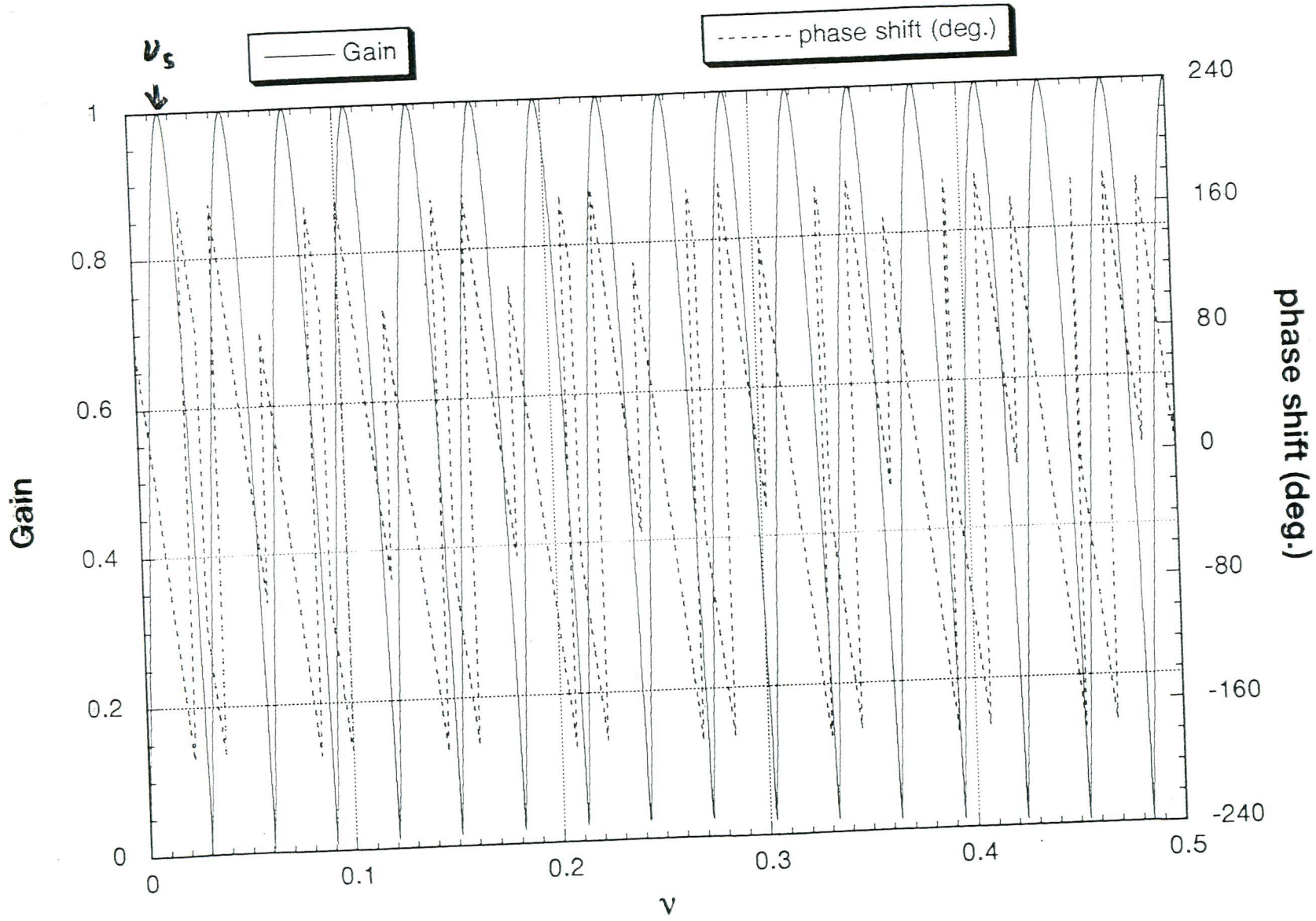
In the 2-tap filters

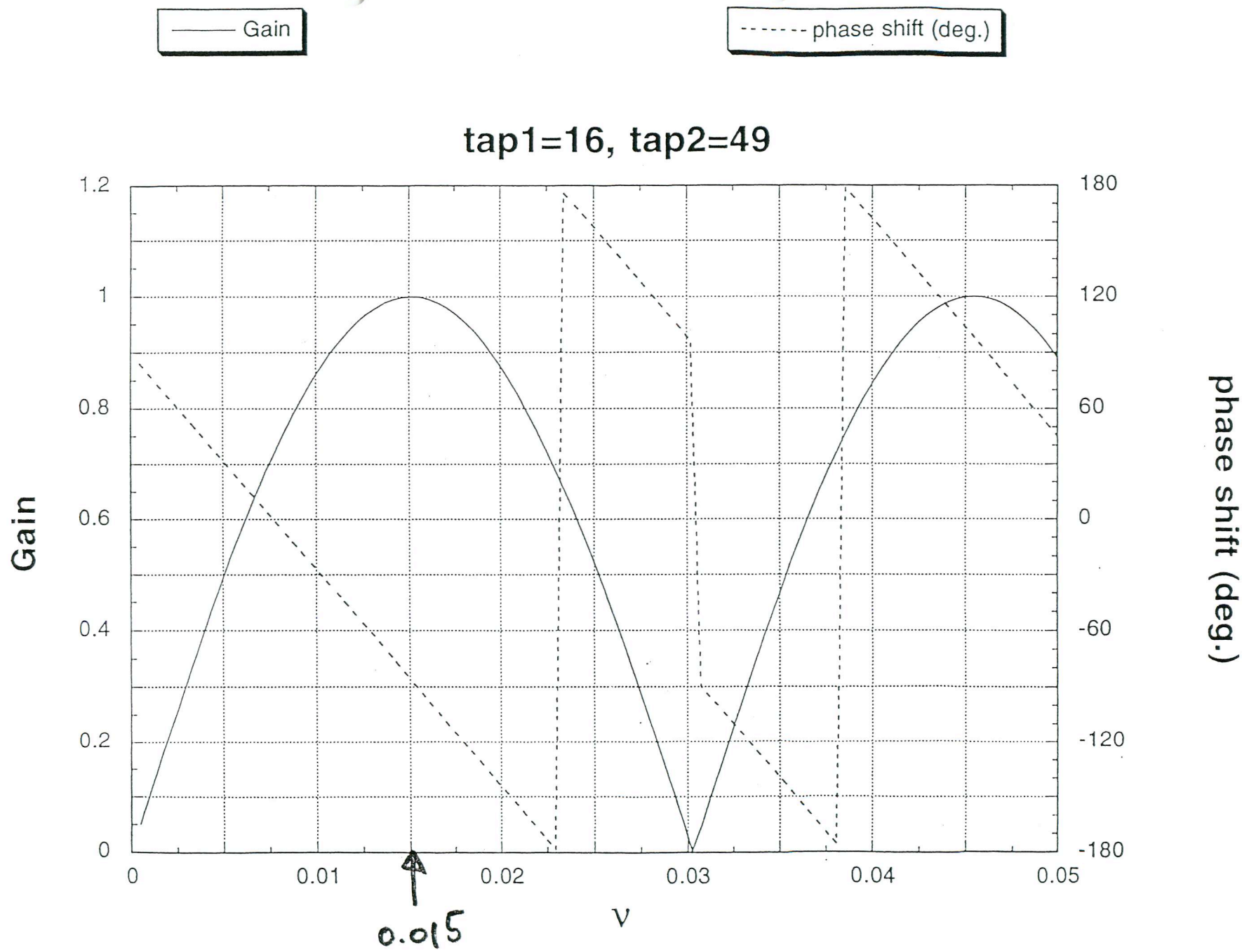
$$y = x_i \ominus x_j$$

By suitably choosing, i and j, various filters will be obtained

The subtraction is executed by a hardware logic.

Frequency Characteristic of 2-tap Filter (longitudinal)




Gain
phase shift (deg.)
tap1=16, tap2=49
1.2
1
0.8
0.6
0.4
0.2
0
180
120
60
0
-60
-120
-180
0
0.01
0.02
0.03
0.04
0.05
Gain
phase shift (deg.)
ν
0.015

The signal Process Board

The signal process board consists of

-- an A to D converter (509MHz)
analog bandwidth is 1.2 GHz (catalog)

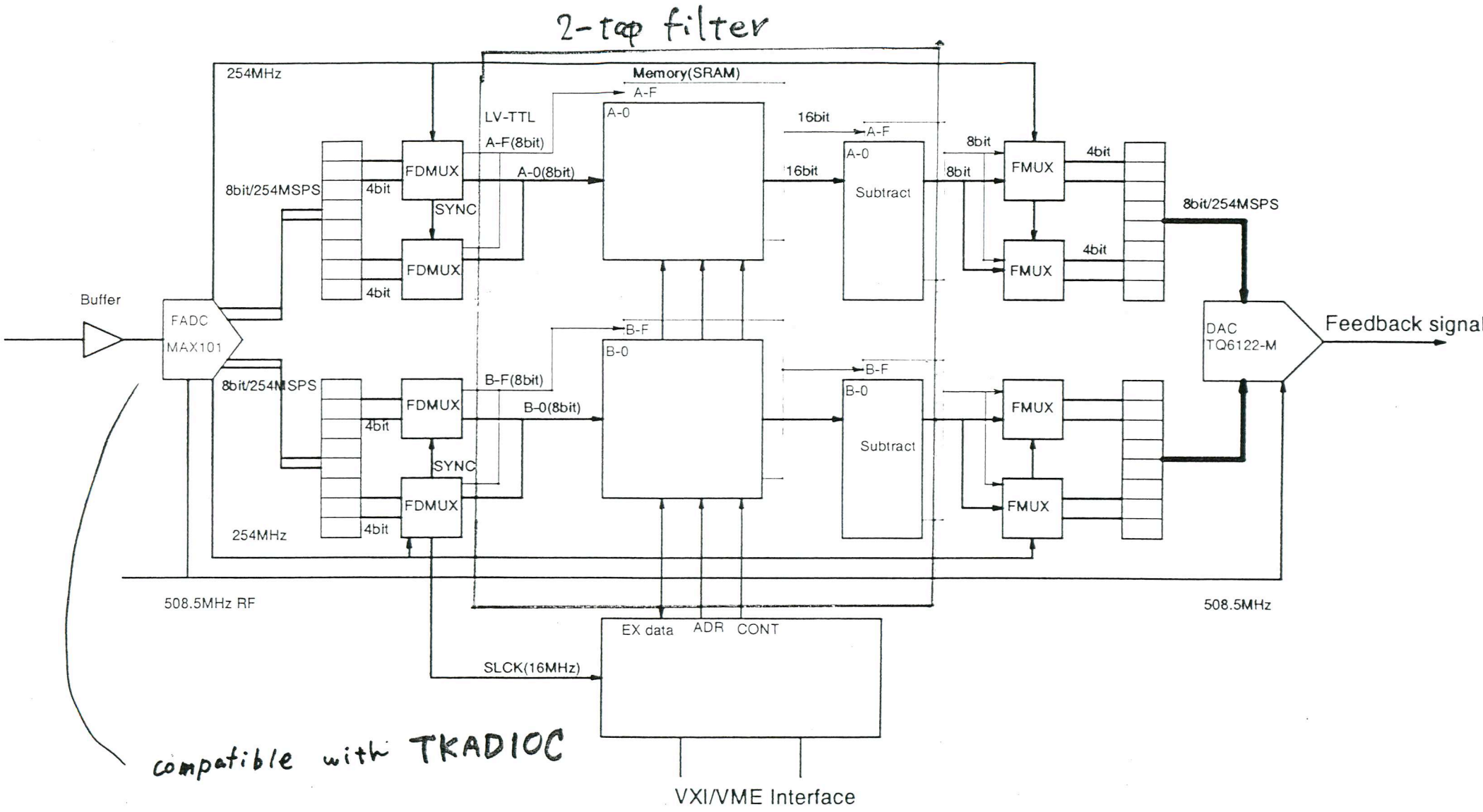
-- de-multiplexers (custom LSI)
509 (254)MHz--> 32 (16) MHz

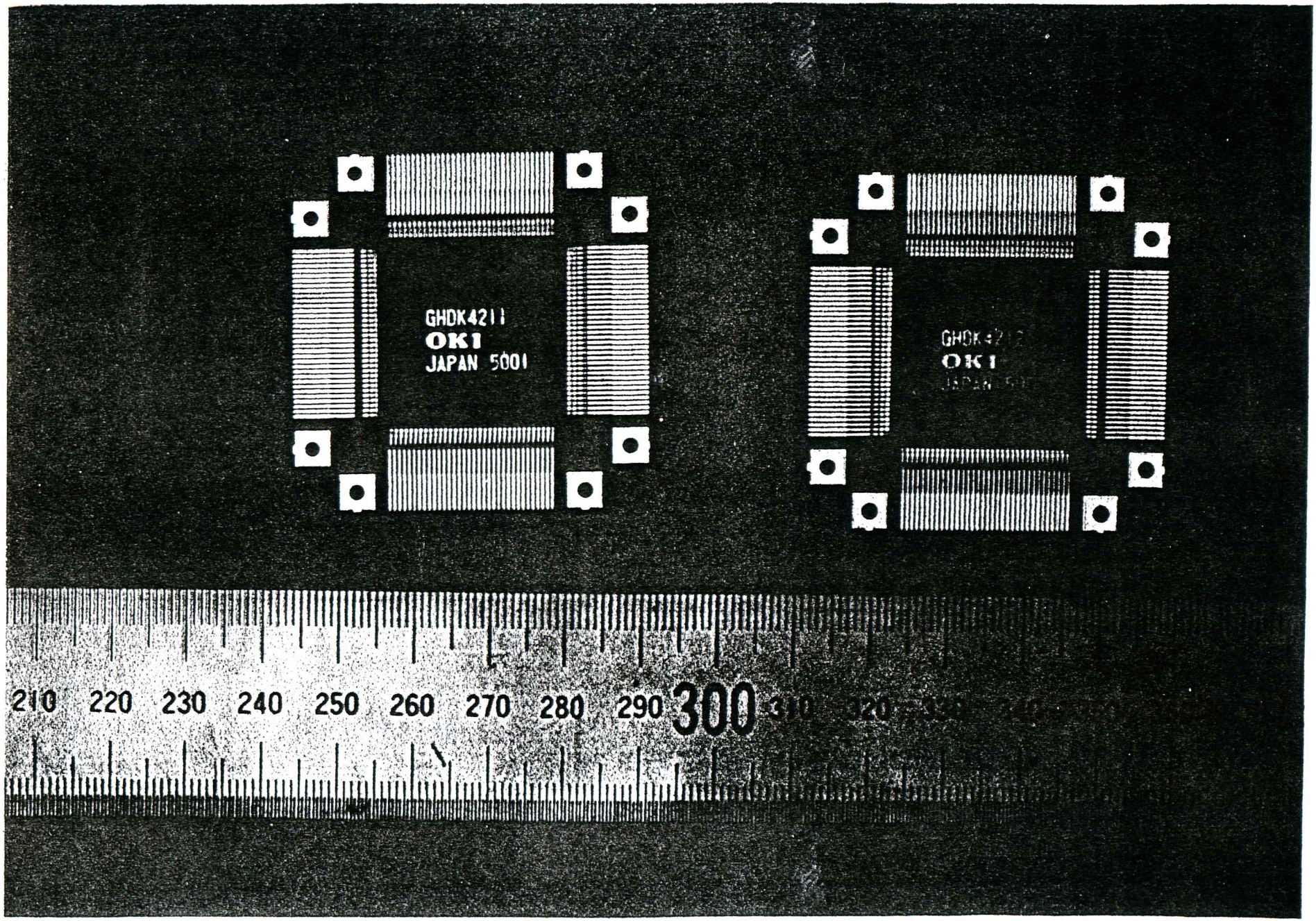
-- *ALUs, memories and their controller*
2-tap digital-filter / simple digital delays

-- multiplexers (custom LSI)
32 (16) MHz --> 509 (254) MHz

-- a D to A converter

♦ Board size --- approximately 3-height VME board


2-tap filter
254MHz
Memory(SRAM)
A-F
LV-TTL
A-F(8bit)
A-0
16bit
A-F
8bit
4bit
FMUX
8bit/254MSPS
4bit
FDMUX
A-0(8bit)
16bit
A-0
Subtract
8bit
SYNC
FDMUX
4bit
4bit
FMUX
8bit/254MSPS
Buffer
FADC
MAX101
B-F
B-0
DAC
TQ6122-M
Feedback signal
B-F
B-F(8bit)
B-0
8bit/254MSPS
FDMUX
4bit
B-0(8bit)
Subtract
FMUX
SYNC
FDMUX
FMUX
254MHz
4bit
508.5MHz RF
508.5MHz
EX data
ADR
CONT
SLCK(16MHz)
compatible with TKAD10C
VXI/VME Interface



GaAs Custom LSIs left: de-multiplexer right multiplexer

Check of the performance of 2-tap filters by Feedback Experiments in AR

- Longitudinal

  Robinson instablity was purposely excited

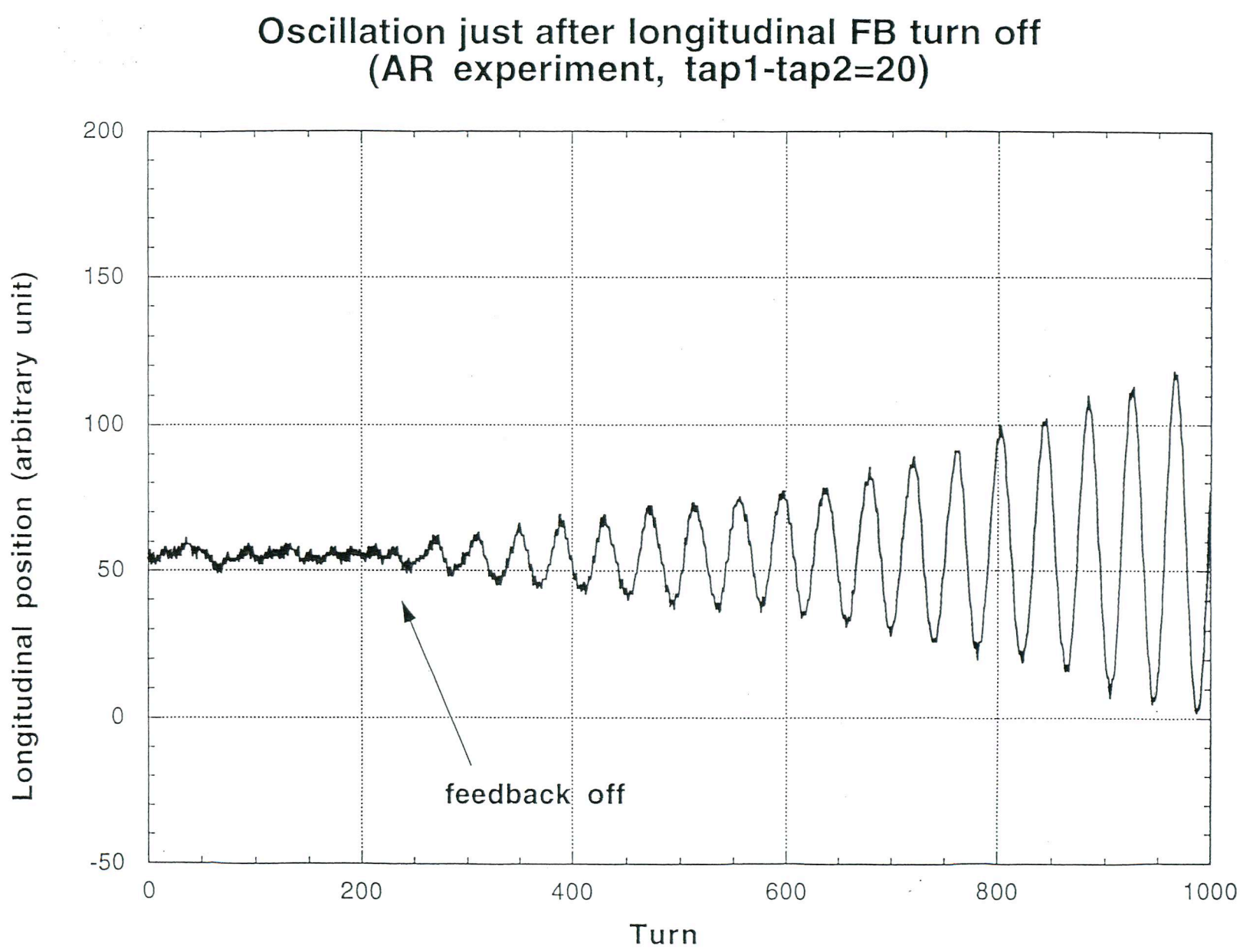
  -------> try to damp it by cavity phase modulation with the feedback signal

  (the feedback kicker was RF cavities)

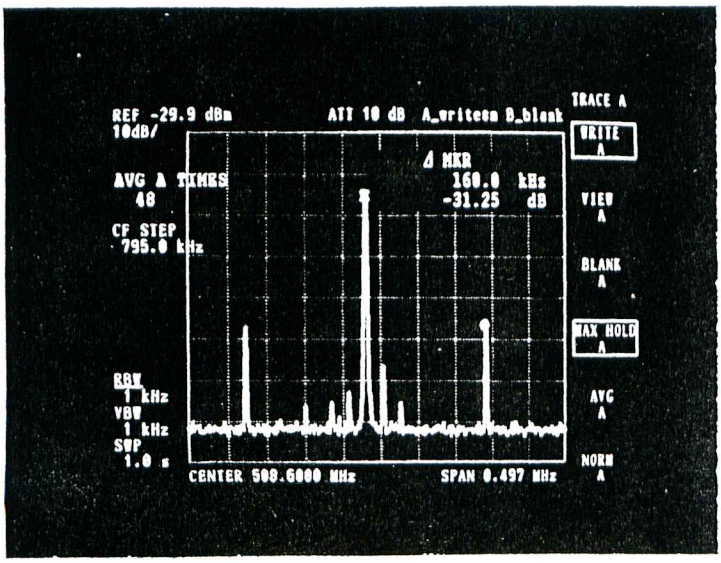
- Transverse

  Kicking the bunch by one set of kickers (excitation)

  -----> try to damp it by kicking with another set of kickers

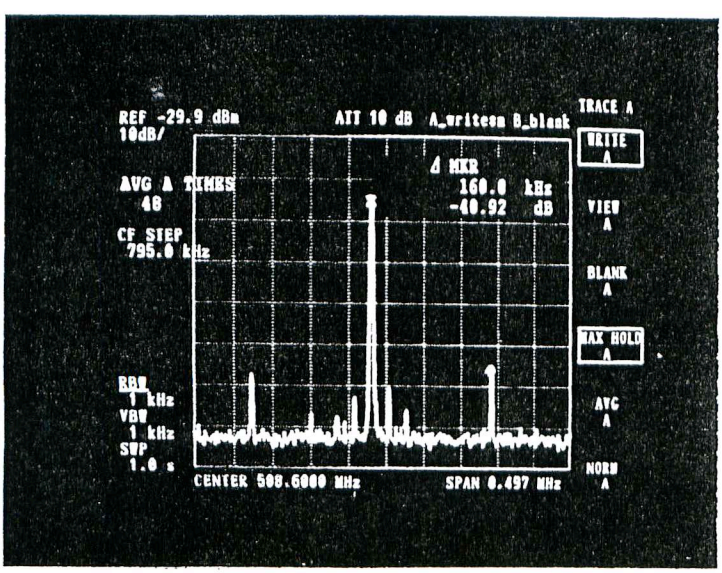

Oscillation just after longitudinal FB turn off
(AR experiment, tap1-tap2=20)
Longitudinal position (arbitrary unit)
200
150
100
50
0
-50
0
200
400
600
800
1000
Turn
feedback off

Experiment in AR



Feedback
OFF

−10 dB



Feedback
ON

タップ位置 18、6
5 2

tap1 = 2 tap2 = 5

Feedback kickers

Electrodes

Longitudinal

travelling wave devices <-----

very low-Q resonators

transverse

usual pairs of striplines

Amplifiers

Solid state, class-A

Transverse Kickers

Two type of transverse kickers will be used

- narrow band (lower band), high shunt impedance
  - -- resistive wall
  - -- beam-electron
  - -- beam-ion
- wide band but relatively low shunt impedance
  - -- HOM of cavities

Stripline kickers for transverse feedback systems

Damping time ~1ms for 1mm oscillation (<20MHz)
~1ms for 0.2mm osciilation (wideband)

LER
(1)Lower-band kicker (10kHz~20MHz)

L=1.2m
gap = 0.06m
Rsh (20MHz) = 100kΩ
Po=500W

expected damping time = 0.99ms (1mm)

(2)Wideband kicker (20MHz~255MHz)

L=0.3m
gap=0.06m
Rsh(255MHz)=4kΩ
Po=1kW

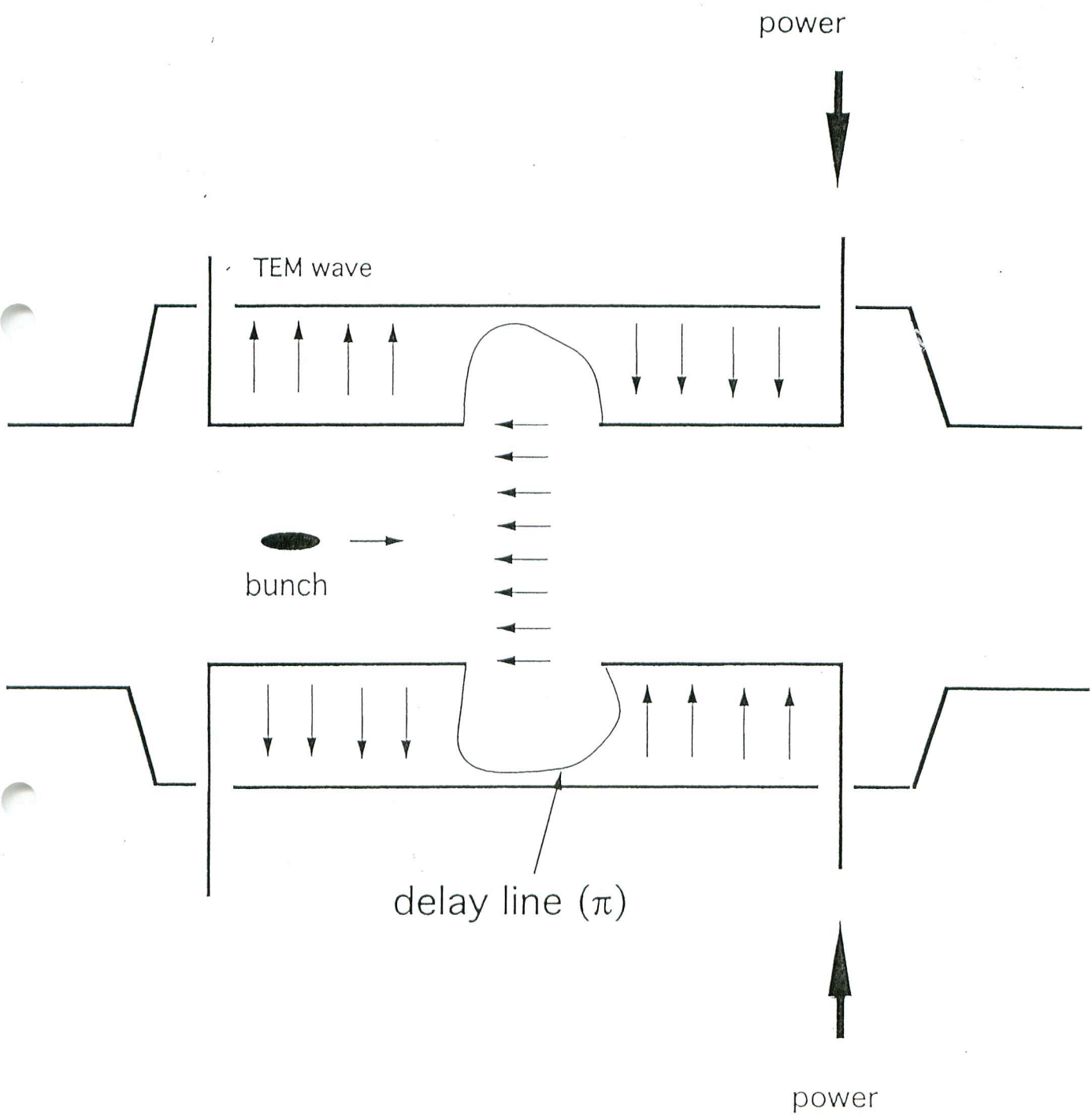
expected damping time=0.7ms (0.2mm)

Longitudinal Kicker

type	:	drift tube (travelling wave)
# of inner electrodes	:	2
input power	:	2 x 500W
shunt impedance	:	~400Ω
center frequency	:	1018 MHz

Idea of this kicker by LBL group
It works in ALS, LPL

Other than this type, there is a possibility of using a very low-Q resonator.



Schematic drawing of the longitudinal kicker

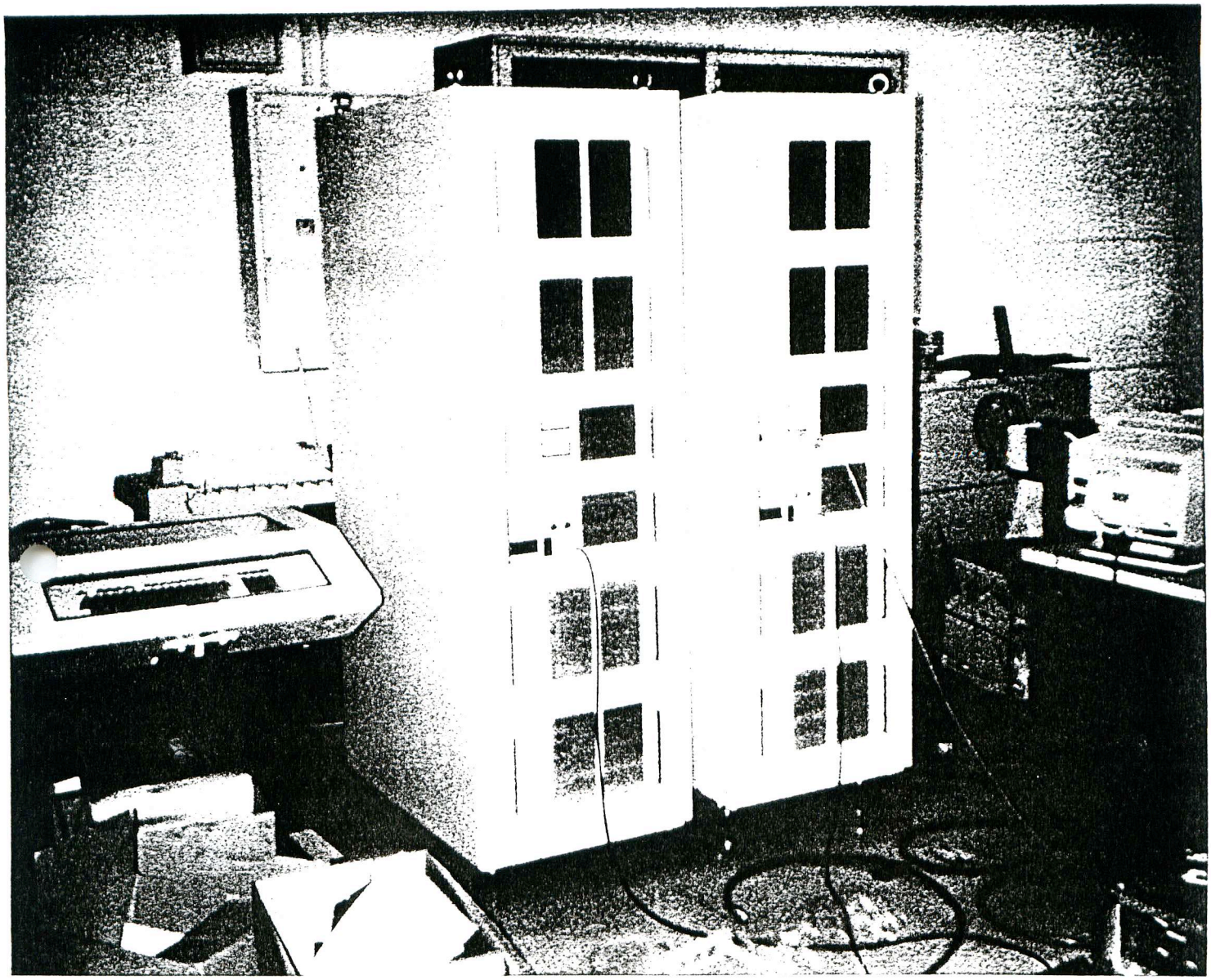
Power Amplifiers for Longi. Feedback

by R&K Company, Japan

Output power	500 W
Center freq.	1 GHz
Bandwidth	250 MHz
Gain	>60 dB

GaAs transisters (FUJITSU FLL120MK x 328)

a kicker is fed by 2 sets of these amplifiers.



Estimation of the power of the Longitudinal kicker

power : 1000 W/unit

R_s : 400 Ω (2 inner electrodes)

Voltage / unit=$\sqrt{2 \bullet 400 \bullet 1000} \cong 900\,\mathrm{V}$

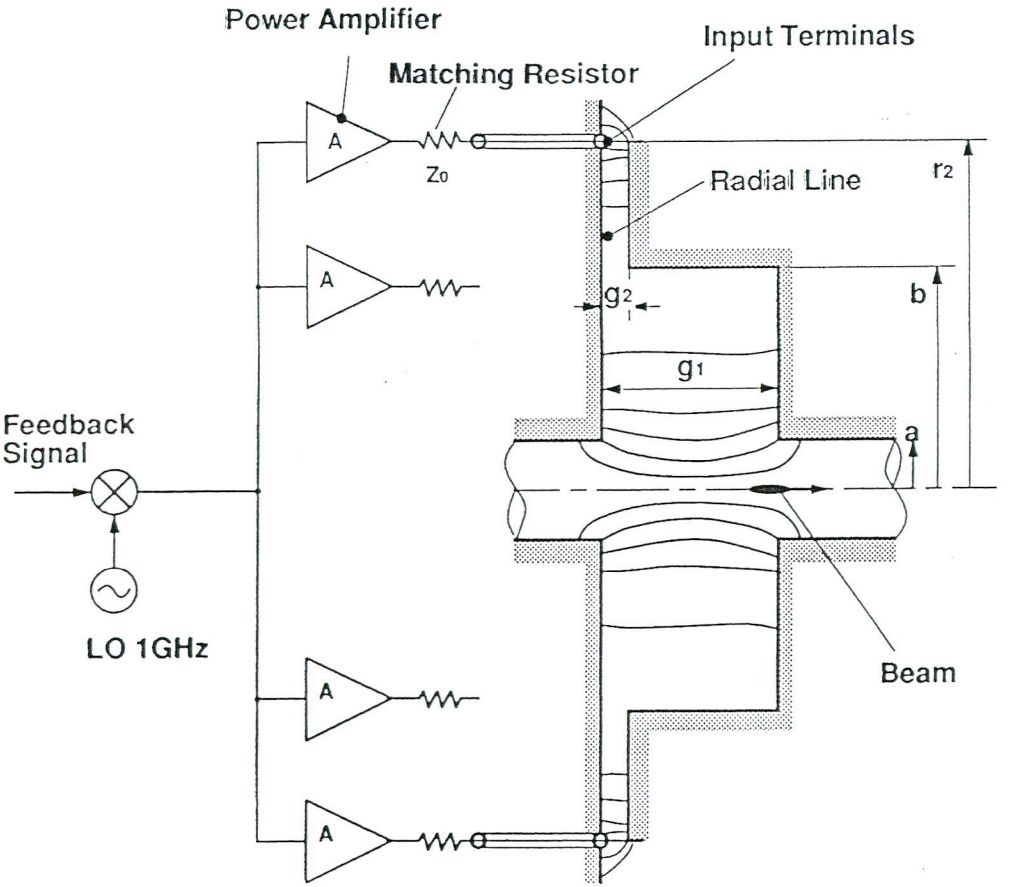
$\Delta E/e$: 2.7×10^{6} eV (σ_ε of LER)

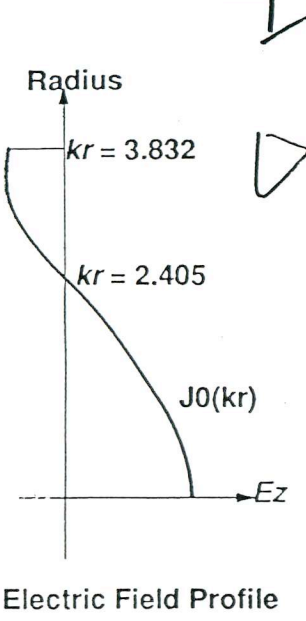
damping rate= $\dfrac{V}{2[T_0(\Delta E/e)]}$

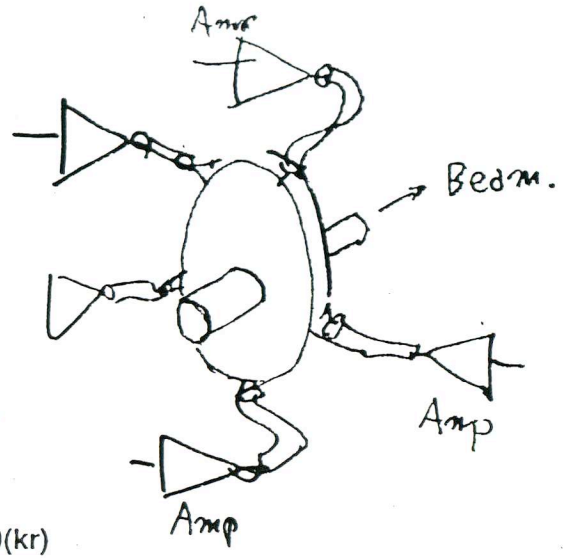
=17 s^{-1} (damping time 60 msec)

We will install a number of the kicker units.

In order to obtain the damping rate of 100 s^{-1},
6 units will be necessary at least.







- Power Combiner & Kicker.

TM-0,1.5,0 Mode Longitudinal Kicker

R&D Status

Pickup :

The basic technique of position detection has been established with the bunch spacing of 2 ns both in longitudinal and transverse planes.
(Experiments in AR, TRISTAN MR, PF RING.)

Signal Process :

- Construction of a prototype of the signal process board (2-tap filter board) has been completed.
We made feedback experiments with this board in AR both in longitudinal and transverse planes(As the feedback kickers we have used some devices which had already been installed in AR.)
The results were successful .
- The construction of fast de-multiplexers and multiplexers have completed.

Kicker Part:

Solid state high-power amplifiers for longitudinal feedback has been constructed. It has satisfactory characteristics. The design / constuction of the longitudinal and transverse kickers is now in progress.

All the parts will be tested carefully within 1-2 year in AR.