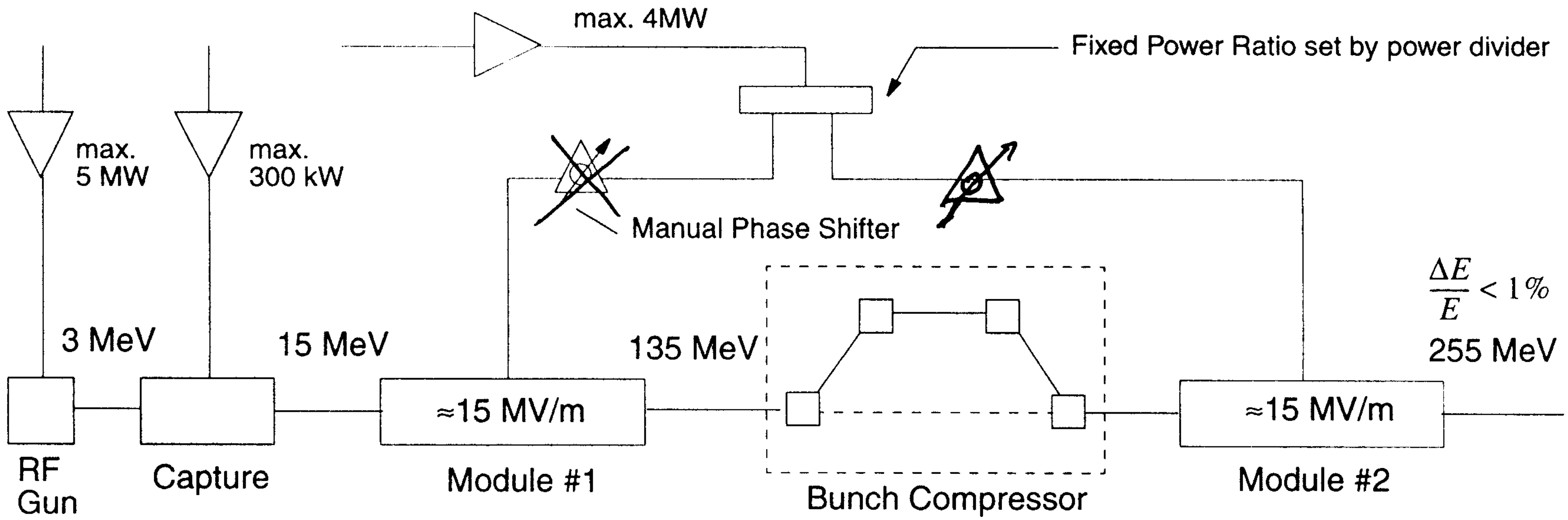
Low-Level RF

S. Simrock, DESY

- RF Control Performance (Aug.–Oct. 99)
  - Configuration
  - Operational Parameters
  - New Operator Interface & Control Algorithm
  - Cavity Phasing
  - Crosstalk between RF Systems
- Cryomodule Conditioning
  - Gradients
  - Lorenz Force Detuning
  - Radiation Levels
- Planned RF Control Upgrades
  - Motorized 3-stub WG Tuners
  - State Machine
  - Down-converters & Vector modulators
- LLRF Design Issues for Tunnel Installation
- Conclusion

TTF

RF System Diagram with Bunch Compressor



Module #1

$V_{acc} = 120\text{MV}$

$\phi_{acc} = -8.7°$

$\frac{\Delta V_{acc}}{V_{acc}} < 1\%$

$\Delta\phi_{acc} < 1°$

Bunch Compressor

$R_{56} = 17.8\text{cm}$

i.e. $\approx 2.8°/\%$

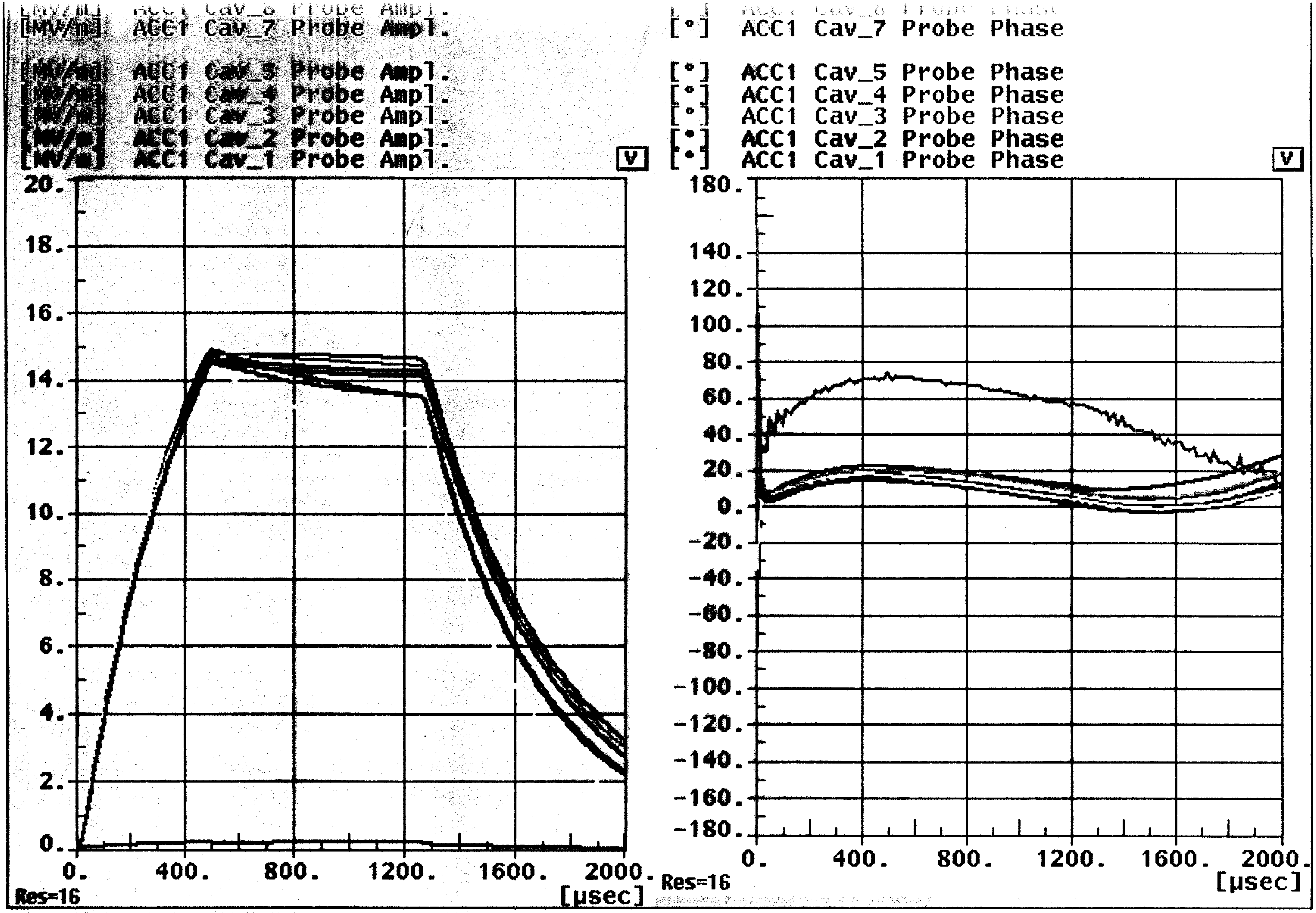
$\Delta l \approx 8.5\text{cm} \approx 130°$

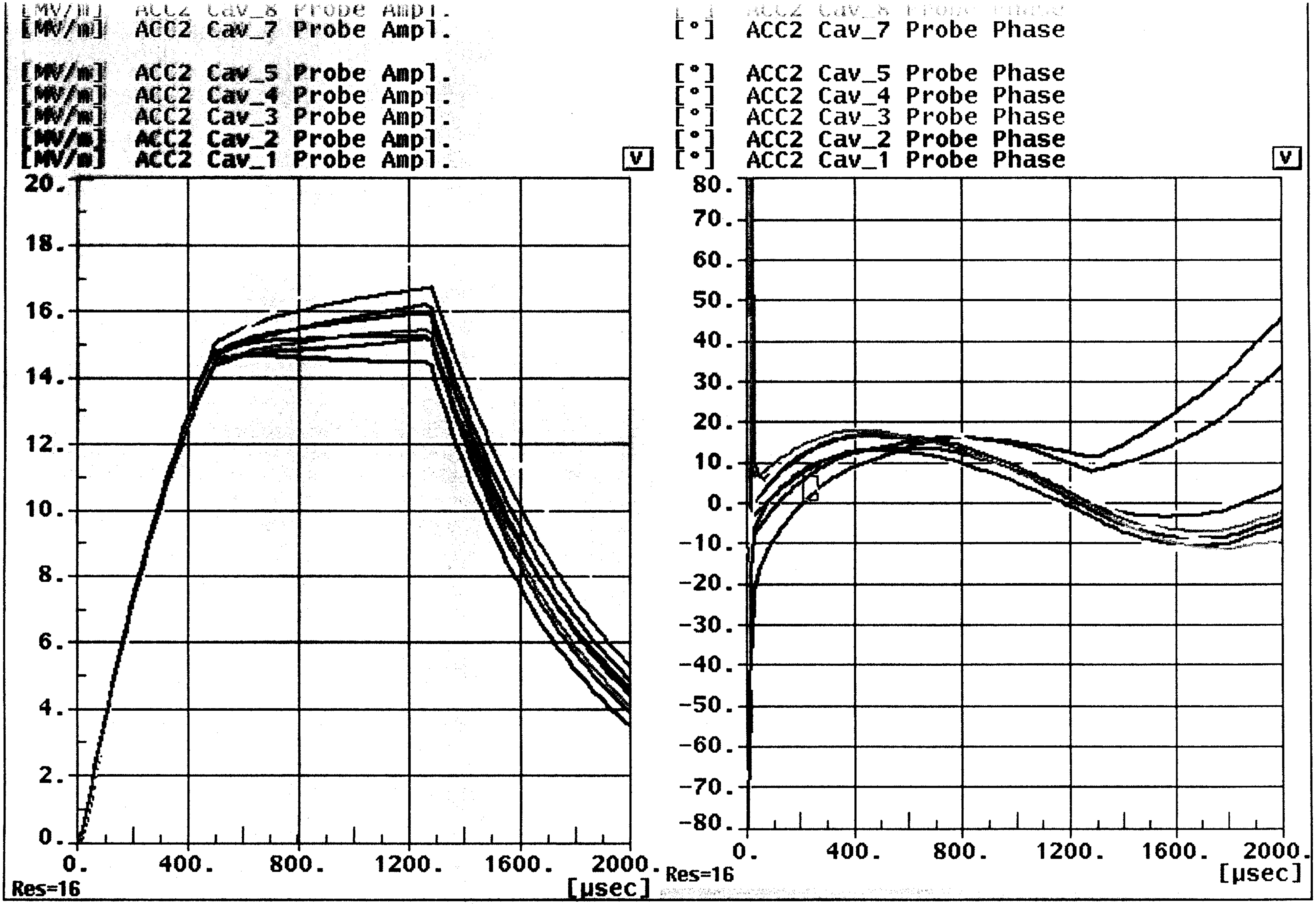
Module #2

$V_{acc} = 120\text{MV}$

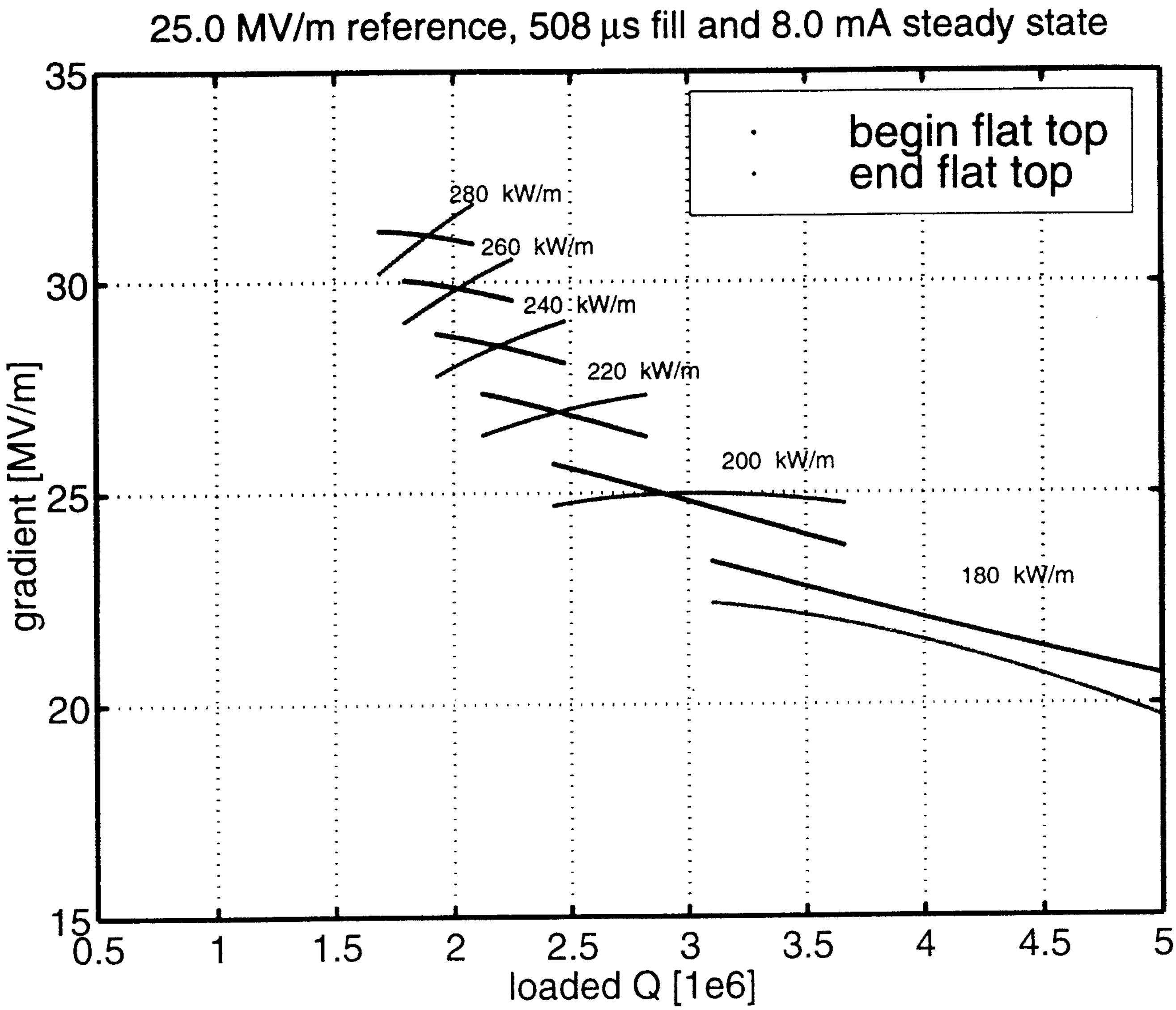
$\phi_{acc} = 0°$

S.Simrock

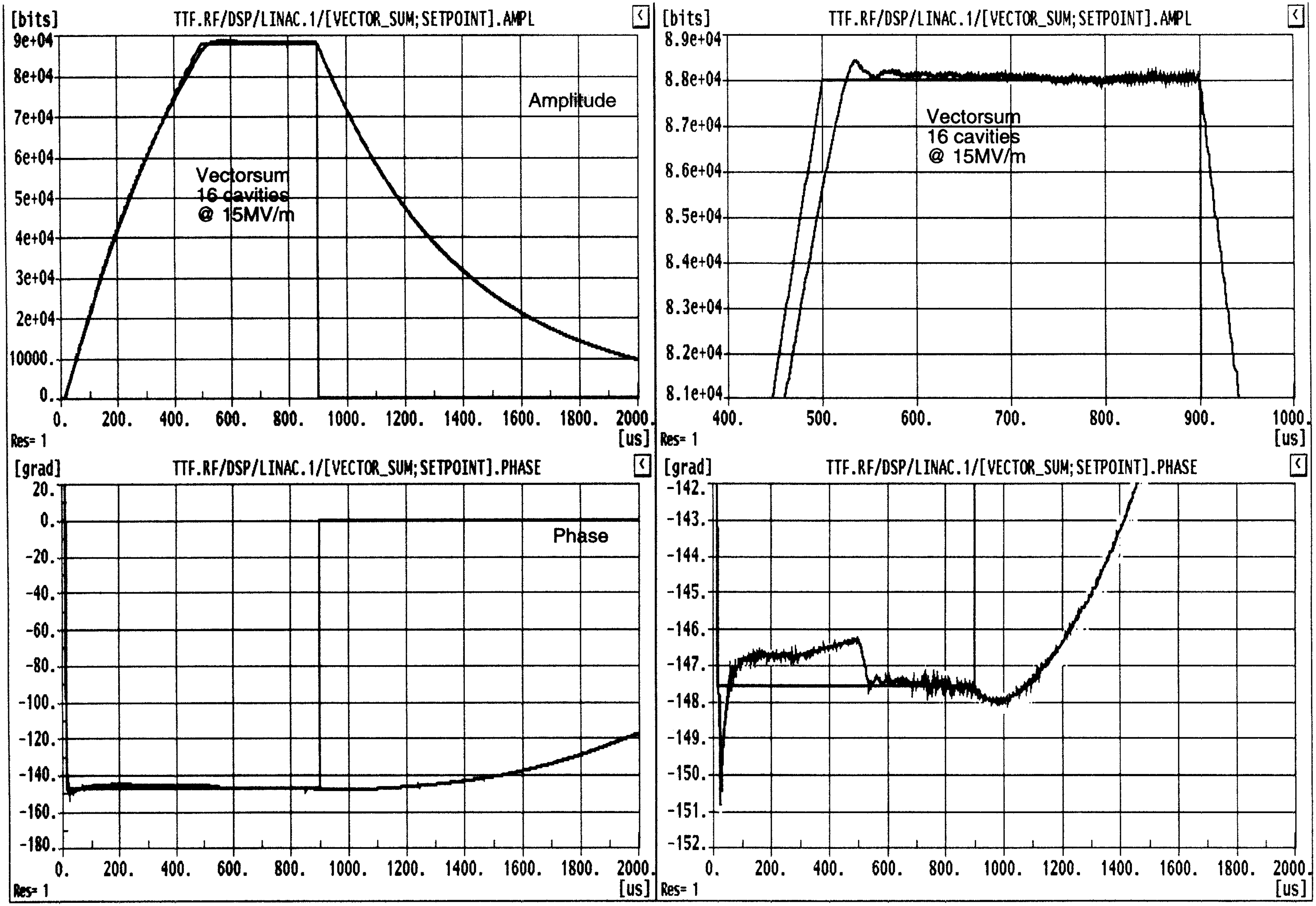

[MV/m] ACC1 Cav_7 Probe Ampl.
[MV/m] ACC1 Cav_5 Probe Ampl.
[MV/m] ACC1 Cav_4 Probe Ampl.
[MV/m] ACC1 Cav_3 Probe Ampl.
[MV/m] ACC1 Cav_2 Probe Ampl.
[MV/m] ACC1 Cav_1 Probe Ampl.
V
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.
0.
400.
800.
1200.
1600.
2000.
[μsec]
Res=16
[°] ACC1 Cav_7 Probe Phase
[°] ACC1 Cav_5 Probe Phase
[°] ACC1 Cav_4 Probe Phase
[°] ACC1 Cav_3 Probe Phase
[°] ACC1 Cav_2 Probe Phase
[°] ACC1 Cav_1 Probe Phase
V
180.
140.
120.
100.
80.
60.
40.
20.
0.
-20.
-40.
-60.
-80.
-100.
-120.
-140.
-160.
-180.
0.
400.
800.
1200.
1600.
2000.
[μsec]
Res=16

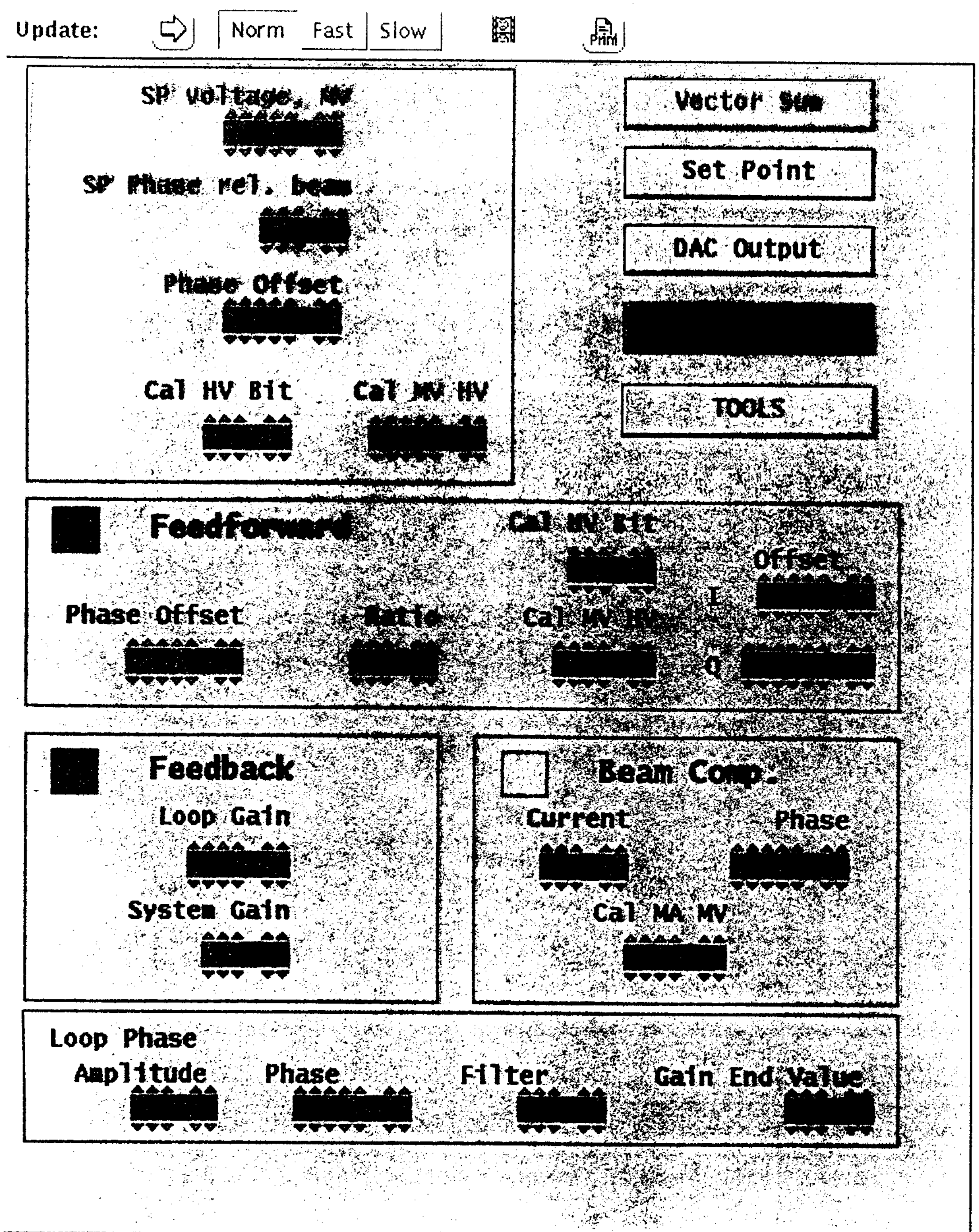


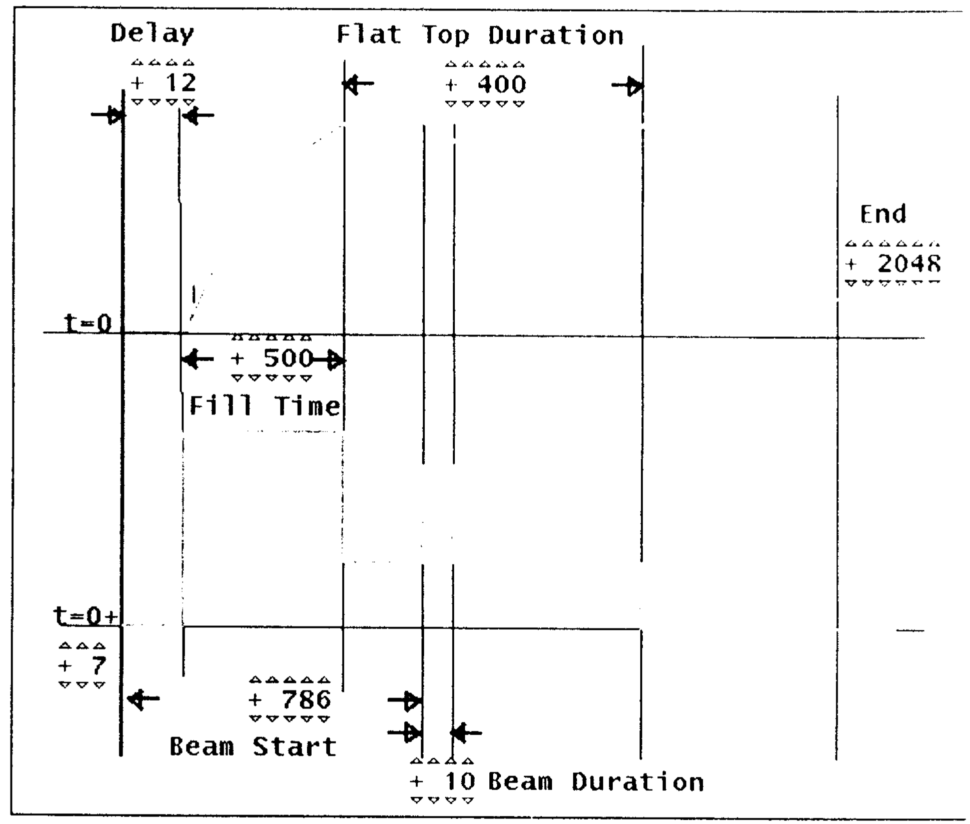
[MV/m] ACC2 Cav_7 Probe Ampl.
[MV/m] ACC2 Cav_5 Probe Ampl.
[MV/m] ACC2 Cav_4 Probe Ampl.
[MV/m] ACC2 Cav_3 Probe Ampl.
[MV/m] ACC2 Cav_2 Probe Ampl.
[MV/m] ACC2 Cav_1 Probe Ampl.
[°] ACC2 Cav_7 Probe Phase
[°] ACC2 Cav_5 Probe Phase
[°] ACC2 Cav_4 Probe Phase
[°] ACC2 Cav_3 Probe Phase
[°] ACC2 Cav_2 Probe Phase
[°] ACC2 Cav_1 Probe Phase
[μsec]
Res=16



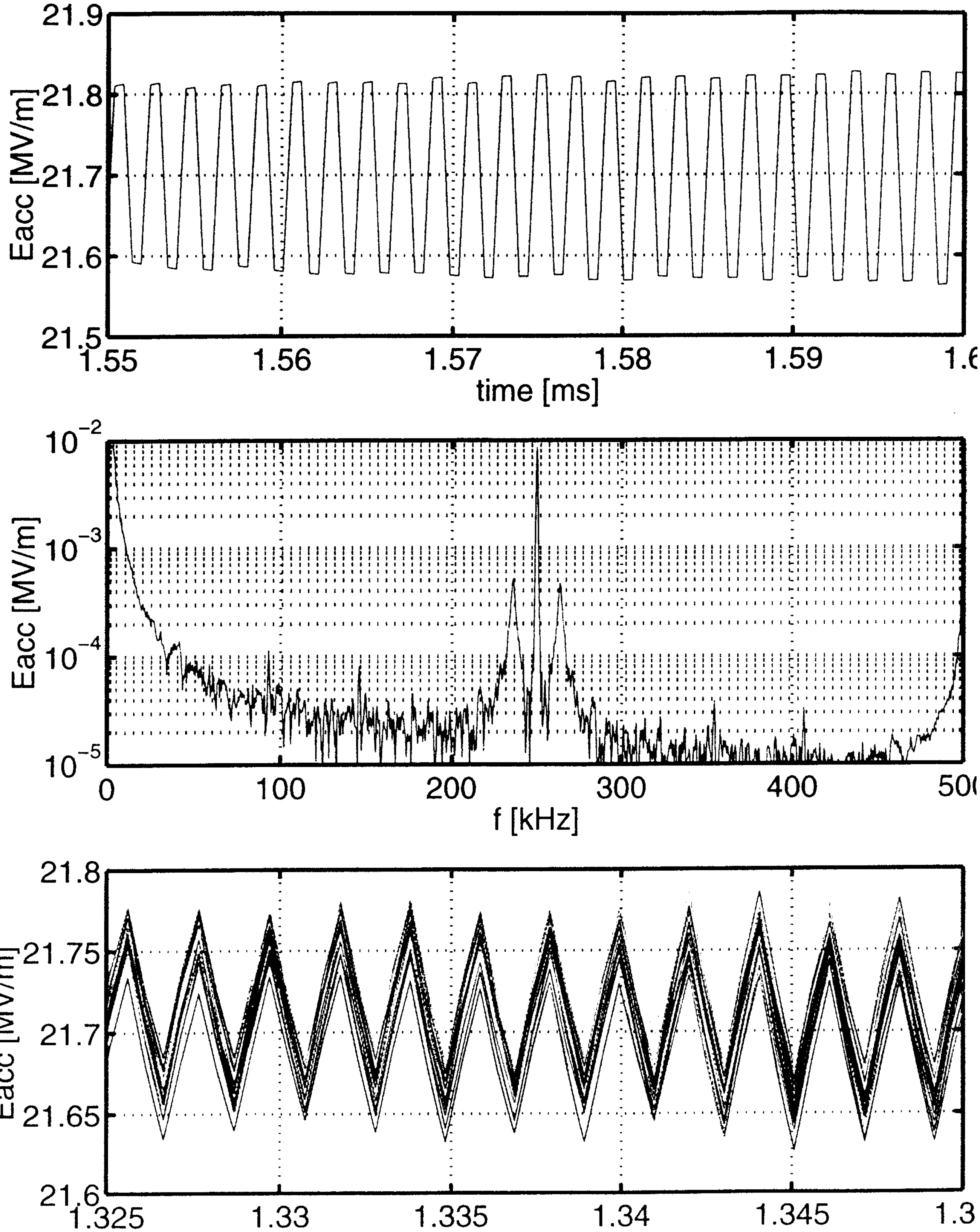
25.0 MV/m reference, 508 μs fill and 8.0 mA steady state
begin flat top
end flat top
280 kW/m
260 kW/m
240 kW/m
220 kW/m
200 kW/m
180 kW/m
gradient [MV/m]
loaded Q [1e6]
35
30
25
20
15
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


[bits]
TTF.RF/DSP/LINAC.1/[VECTOR_SUM;SETPOINT].AMPL
Amplitude
Vectorsum
16 cavities
@ 15MV/m
Res= 1
[us]
[bits]
TTF.RF/DSP/LINAC.1/[VECTOR_SUM;SETPOINT].AMPL
Vectorsum
16 cavities
@ 15MV/m
Res= 1
[us]
[grad]
TTF.RF/DSP/LINAC.1/[VECTOR_SUM;SETPOINT].PHASE
Phase
Res= 1
[us]
[grad]
TTF.RF/DSP/LINAC.1/[VECTOR_SUM;SETPOINT].PHASE
Res= 1
[us]


Update:
Norm
Fast
Slow
Vector Sum
Set Point
DAC Output
TOOLS
Phase Offset
Cal HV Bit
Feedforward
Offset
Phase Offset
Feedback
Loop Gain
System Gain
Beam Comp.
Current
Phase
Cal MA MV
Loop Phase
Amplitude
Phase
Filter
Gain End Value


Delay
+ 12
Flat Top Duration
+ 400
End
+ 2048
t=0
+ 500
Fill Time
t=0+
+ 7
+ 786
Beam Start
+ 10 Beam Duration

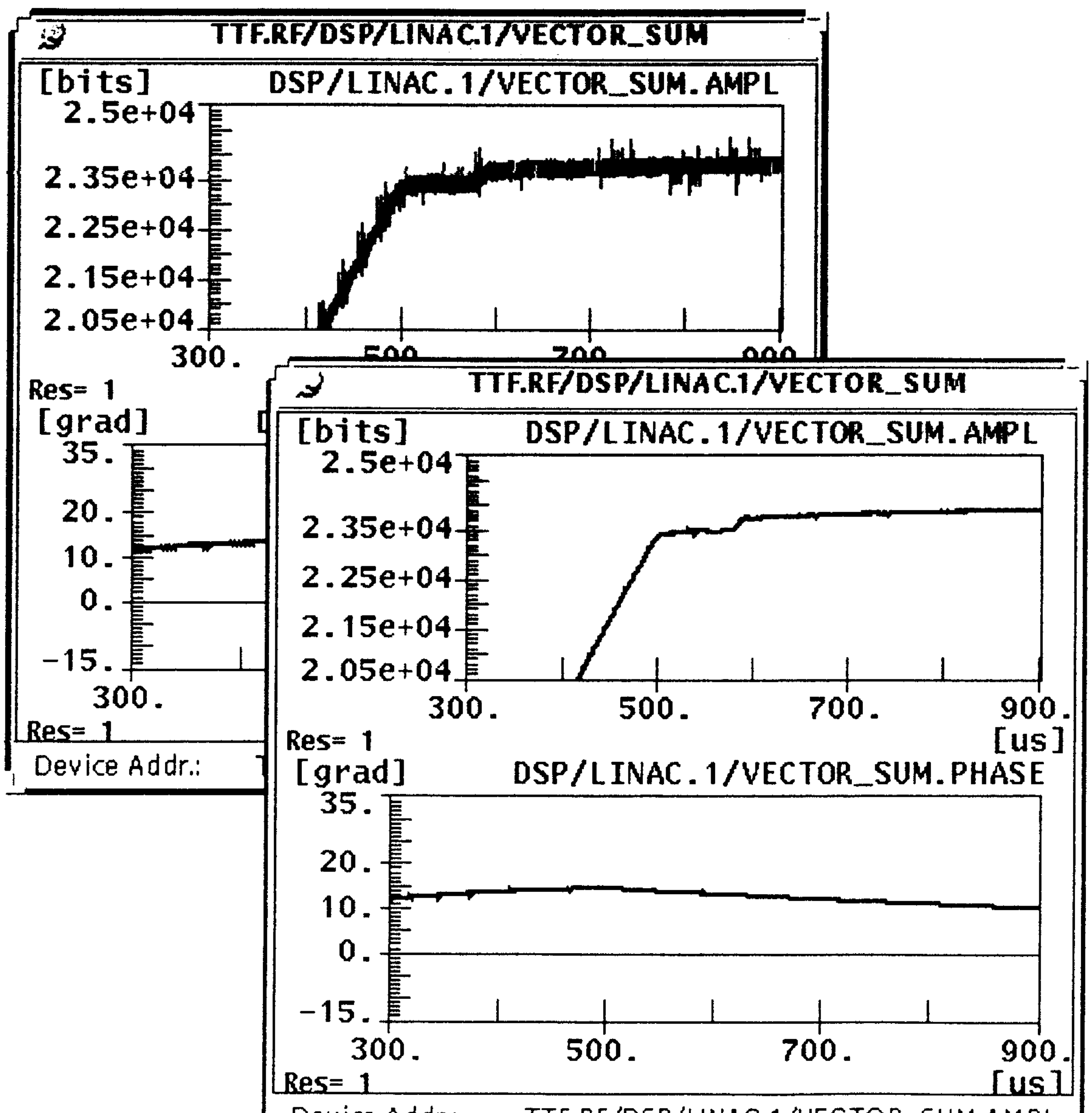
Detector Noise



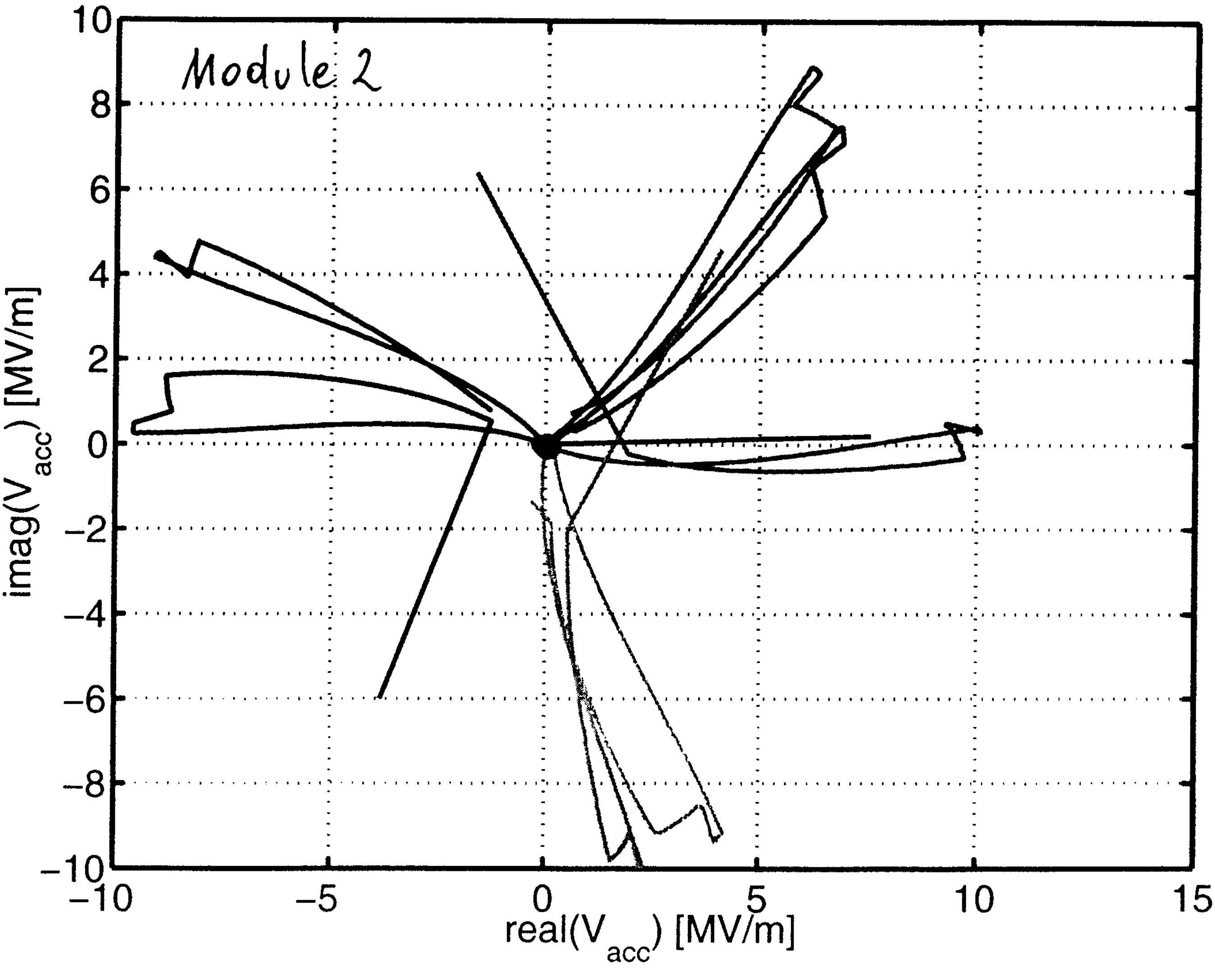
S.Simrock

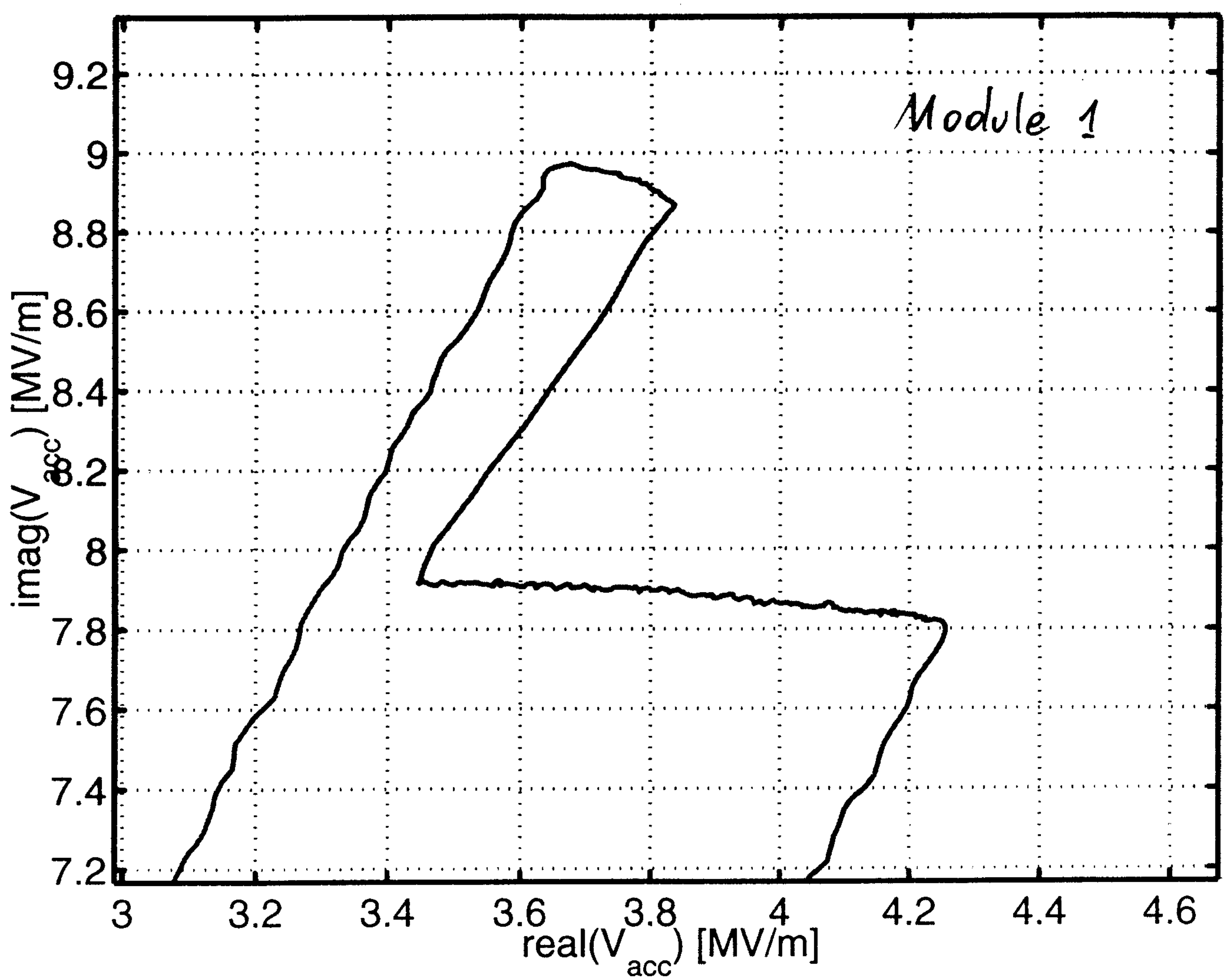
Ripple table

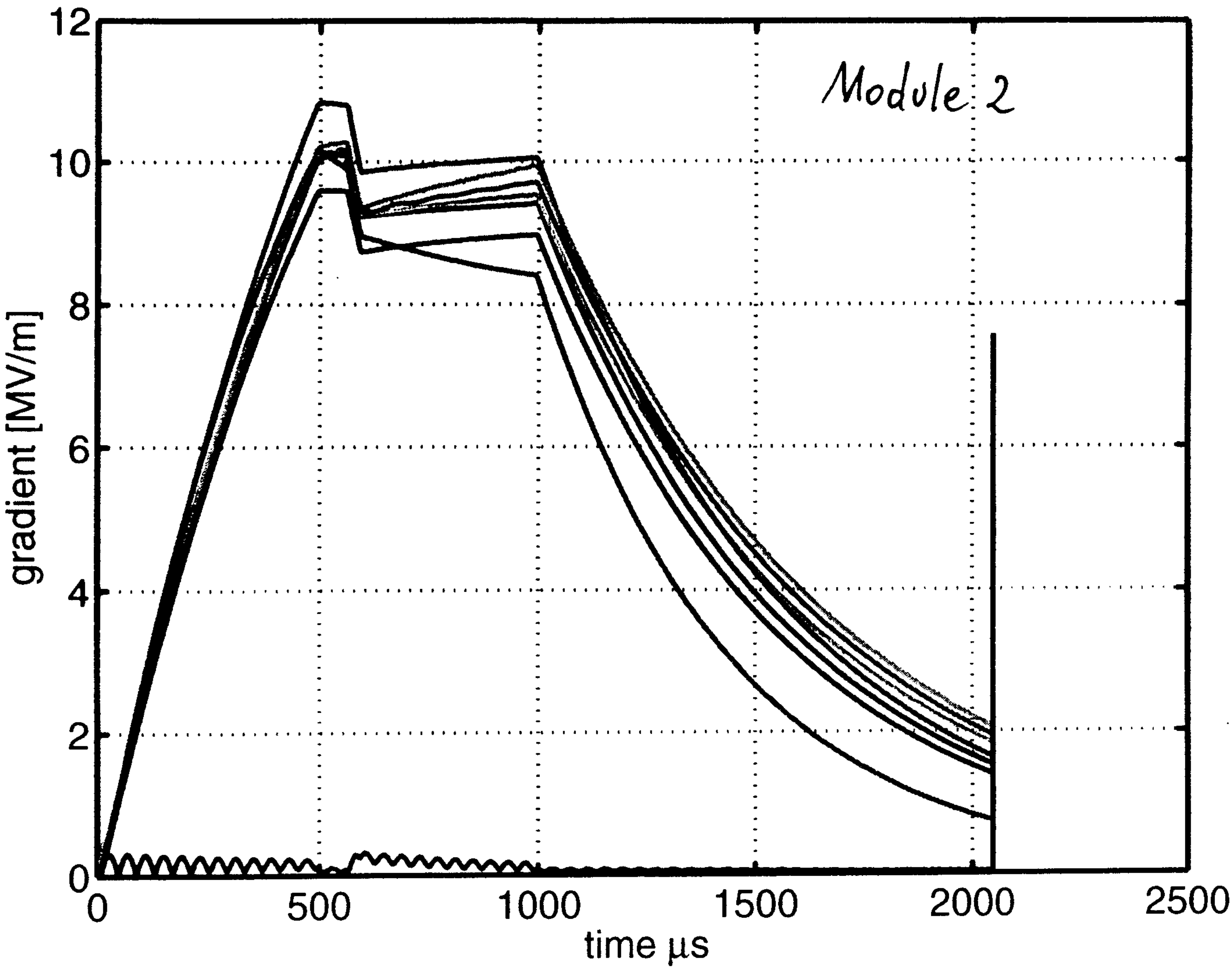
- enables a correction scheme for the systematic error from down conversion to 250kHz IF
- replaces simpler filtering schemes and allows feedback with higher gain



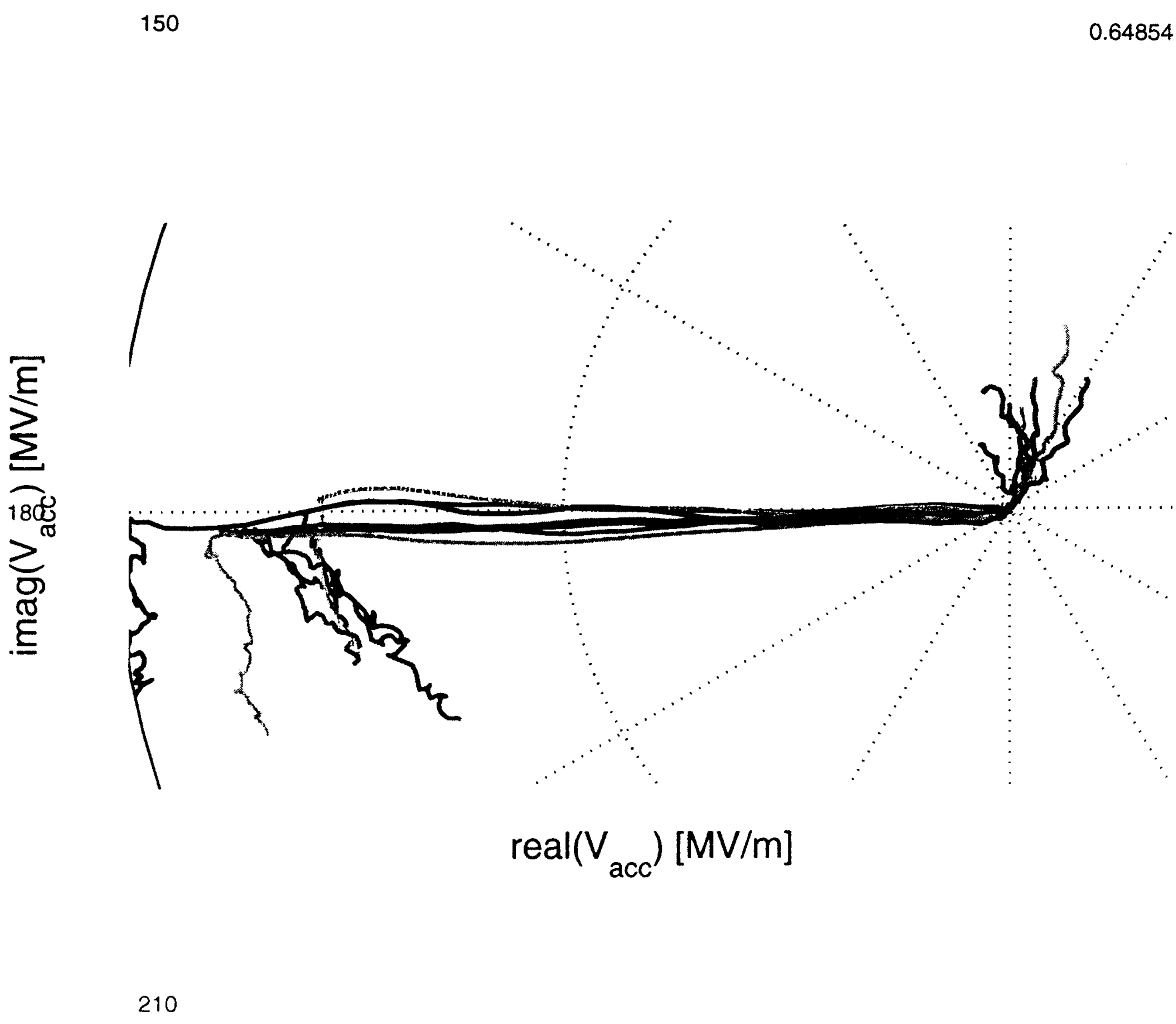
G. von Walter


Module 2
10
8
6
4
2
0
−2
−4
−6
−8
−10
imag(V_acc) [MV/m]
−10
−5
0
5
10
15
real(V_acc) [MV/m]

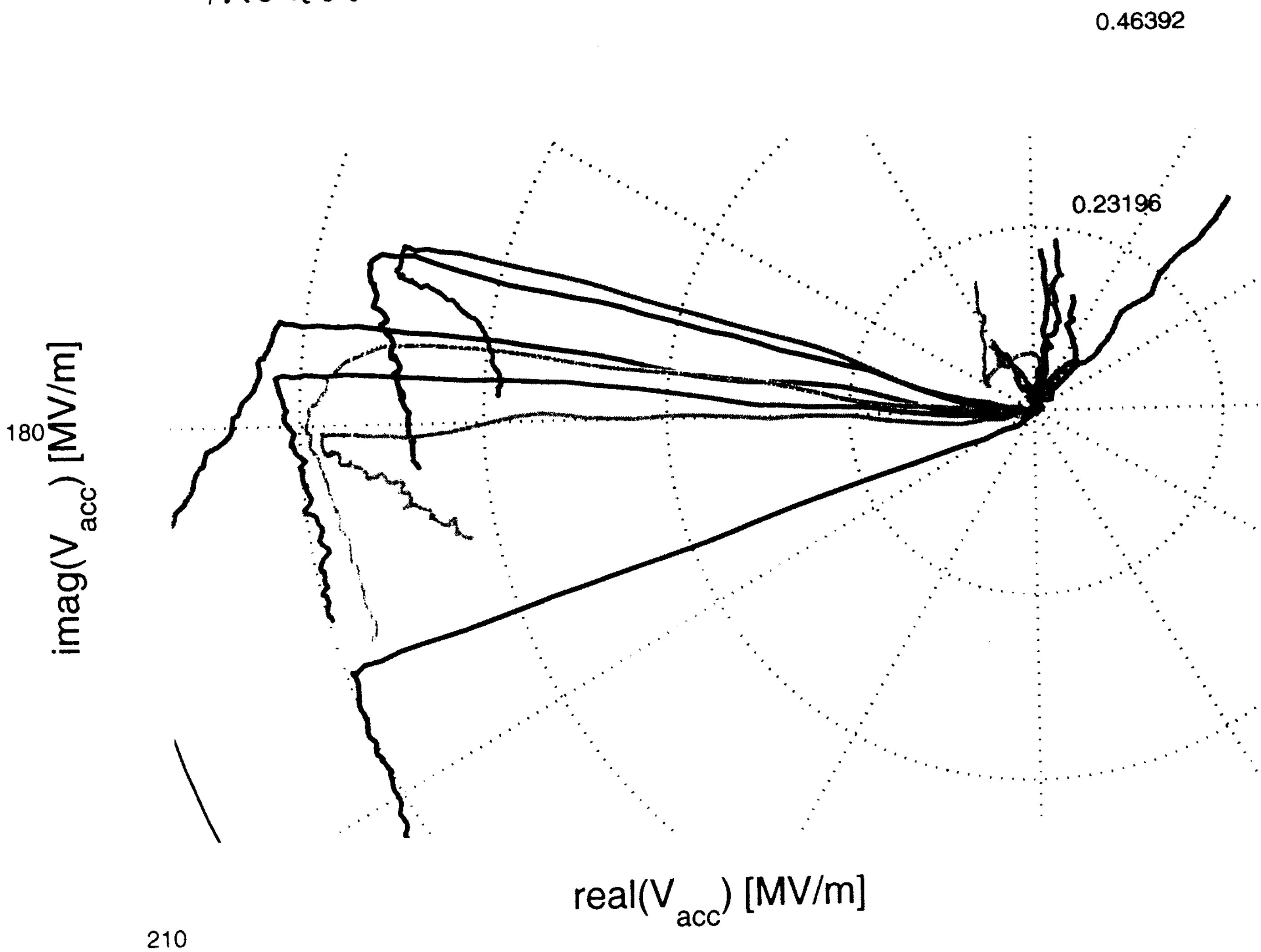

Module 1
imag(V_acc) [MV/m]
real(V_acc) [MV/m]
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6



Module 2
gradient [MV/m]
time µs
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500

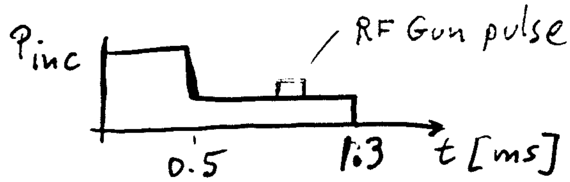

150
0.64854
180
210
imag(V_acc) [MV/m]
real(V_acc) [MV/m]

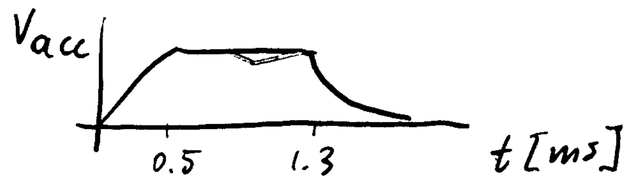
Module 2



Crosstalk

- RF Gun pulse structure (klys. 3) is observed on incident power to the cryomodules (klys. 2) and vice versa
  - amplitude 0-10% varying with time
  - real rf crosstalk (not groundloops) since RF phase dependent



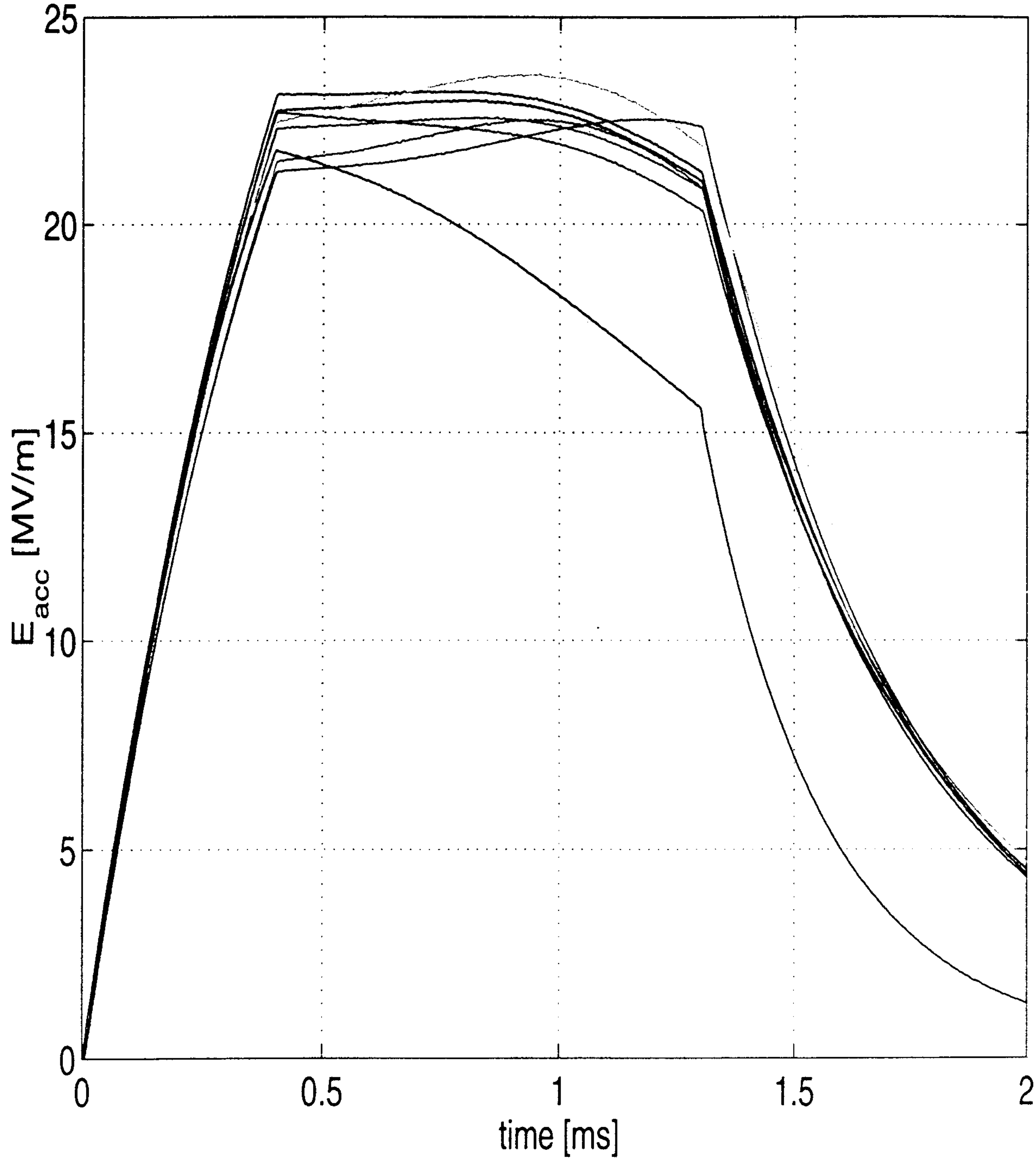


- Attempt to localize source of crosstalk
  - Operate with separate RF generator
  - Pulse generator to control vector-modulator
  - Remove individual LLRF components
  - RF leakage measurements

- Results
  - RF crosstalk distributed over several components (vect. mod, gates, cables ....)
  - Not understood mechanism

TTF

Cavity Gradients (First Cryomodule)



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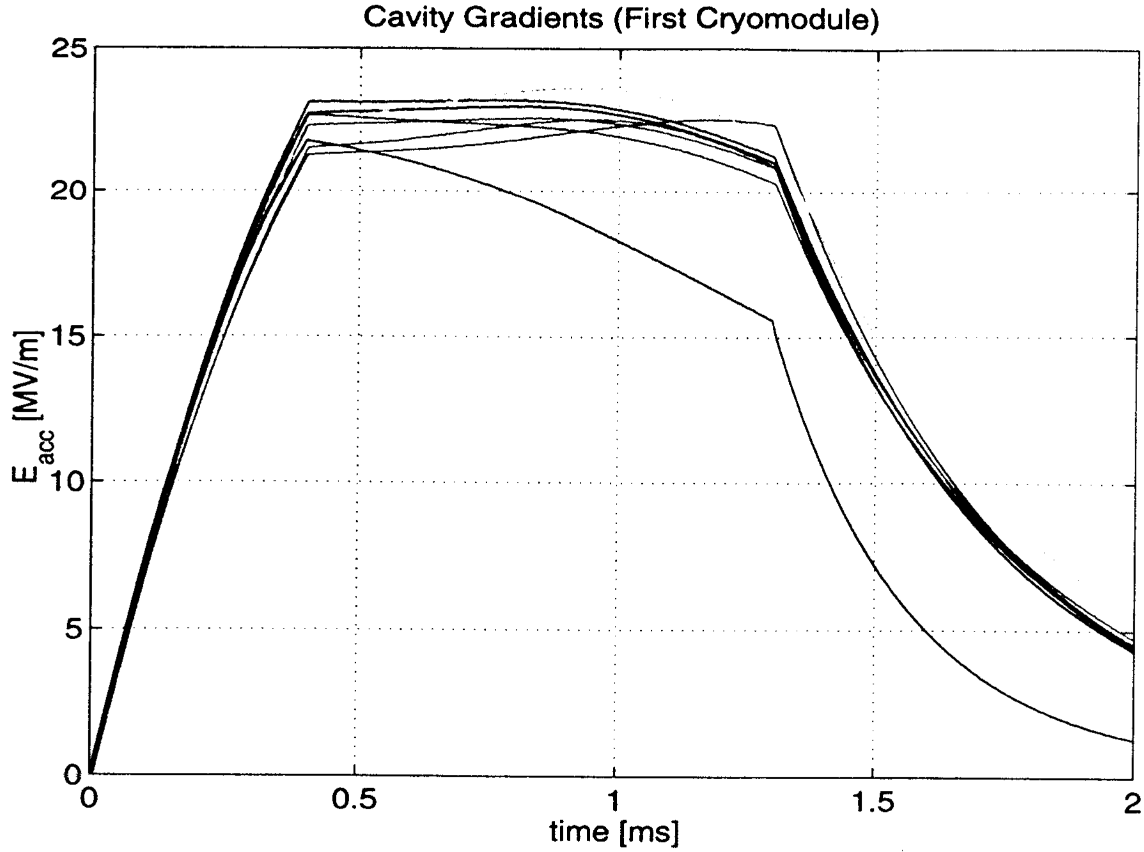
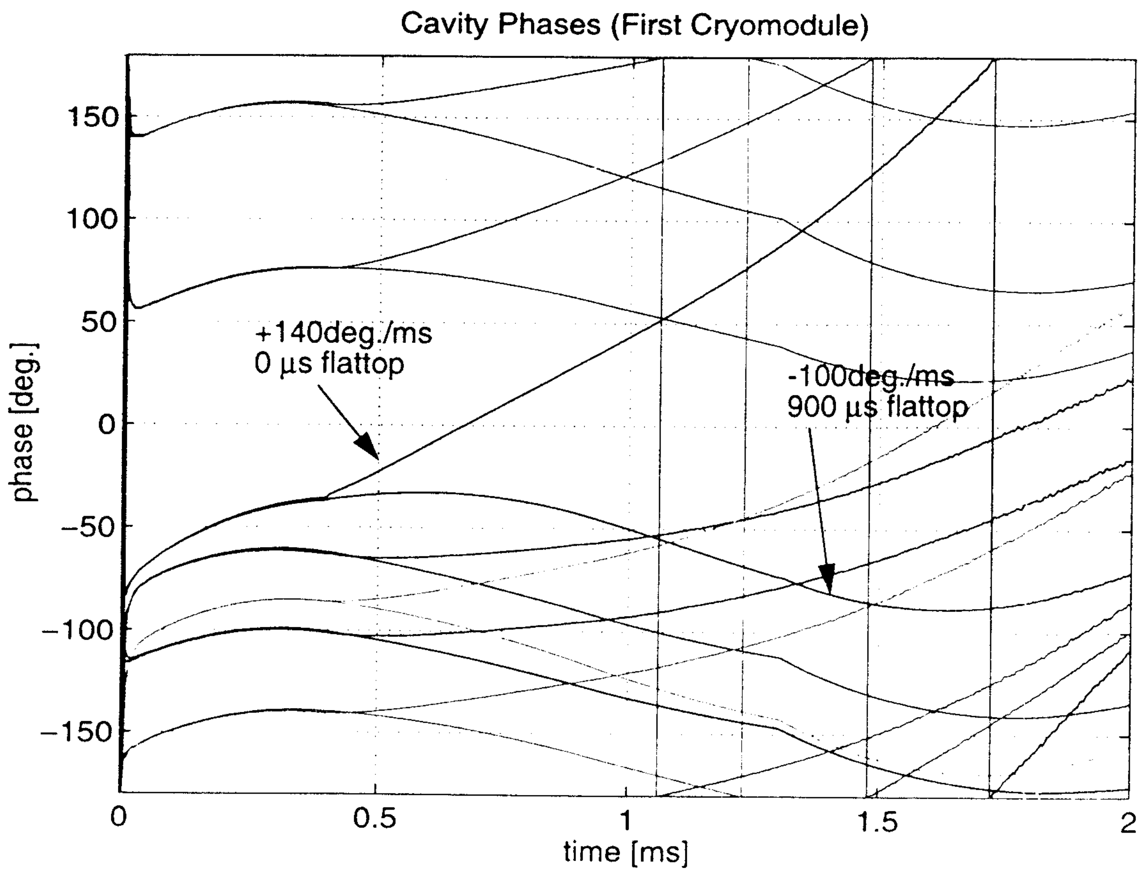
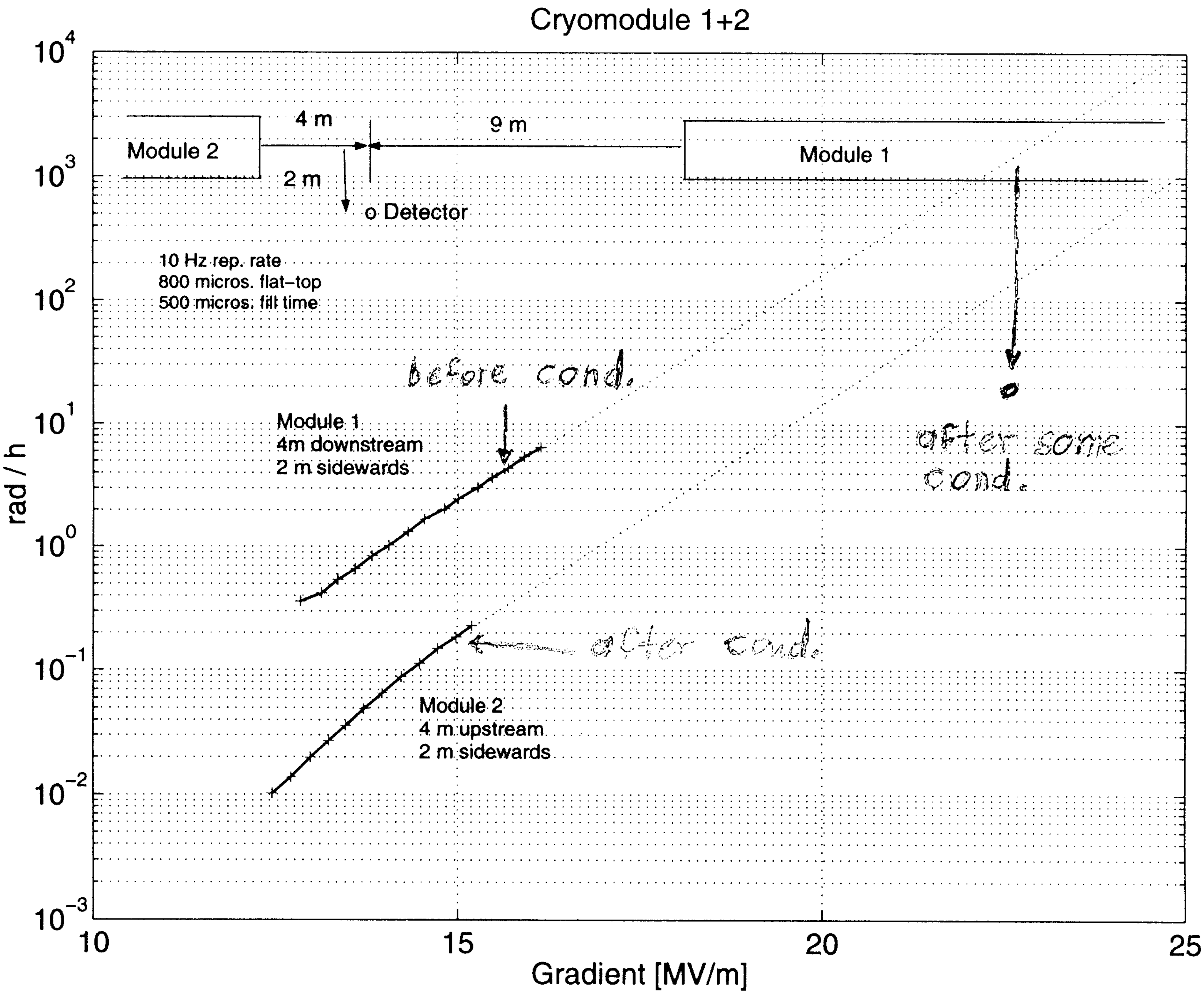

Cavity Gradients (First Cryomodule)
E_{acc} [MV/m]
time [ms]
0
5
10
15
20
25
0.5
1
1.5
2


Cavity Phases (First Cryomodule)
phase [deg.]
time [ms]
+140deg./ms
0 µs flattop
-100deg./ms
900 µs flattop
150
100
50
0
−50
−100
−150
0.5
1
1.5
2



Cryomodule 1+2
Module 2
4 m
2 m
9 m
Module 1
o Detector
10 Hz rep. rate
800 micros. flat-top
500 micros. fill time
before cond.
Module 1
4m downstream
2 m sidewards
after some cond.
after cond.
Module 2
4 m upstream
2 m sidewards
rad / h
Gradient [MV/m]

RF Control Upgrades

- Remote Control of Waveguide tuners
  - Each of 3 stubs controlled with stepper motor
  - Individual position redd out
  - One set of stepper motor drivers for 16 cavities
  - Multiplexing of stepper motor drivers
  - Prototype unit under construction

- State Machine under development
  - Automate RF Gun start-up
  - Automate closing of feedback loop for cryomodules

- Downconverter + vector modulator
  - Single chip (AD 8346) solution available for vector-modulator
  - Plan to replace high level mixers in downconverter with analog multipliers (AD 8343 !)

LLRF Design for TESLA Tunnel

- 32 cavity control
- DSP upgrade (C40 → C67)
- 9MHz frequency distribution with local multipliers and LO-generation

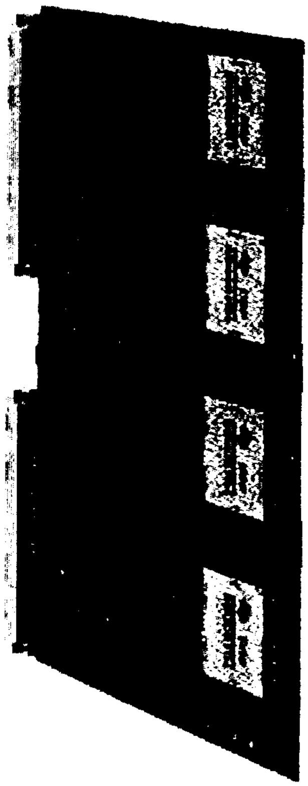
Some tunnel installation issues

- Radiation & Shielding
- Space available for electronics
- Layout of RF control racks
  - EMV Shielding
  - Forced air cooling
  - Grounding scheme
  - Maintenance Access
  - Cabling (RF, analog, digital, fiber optic)

New!

Model 4291

Configurable Quad TMS320C6701 Processor VME Board



General Information

Pentek's Model 4291 features Texas Instruments' new TMS320C6701 floating-point digital signal processor which employs the VelociTI ™ architecture to achieve a remarkable 1 GFLOPS performance.

Incorporating four of these devices, the Model 4291 is a single-slot 6U VMEbus board delivering up to 4 GFLOPS of processing power and a wealth of high-speed interface options to handle the 'C6701's voracious appetite for data.

Since the 'C6701 shares a common set of development tools with the fixed-point 'C6201, you can easily migrate code developed on Pentek's Model 4290 Quad 'C6201 Processor. Models 4290 and 4291 are architecturally identical and support the same set of peripheral interfaces.

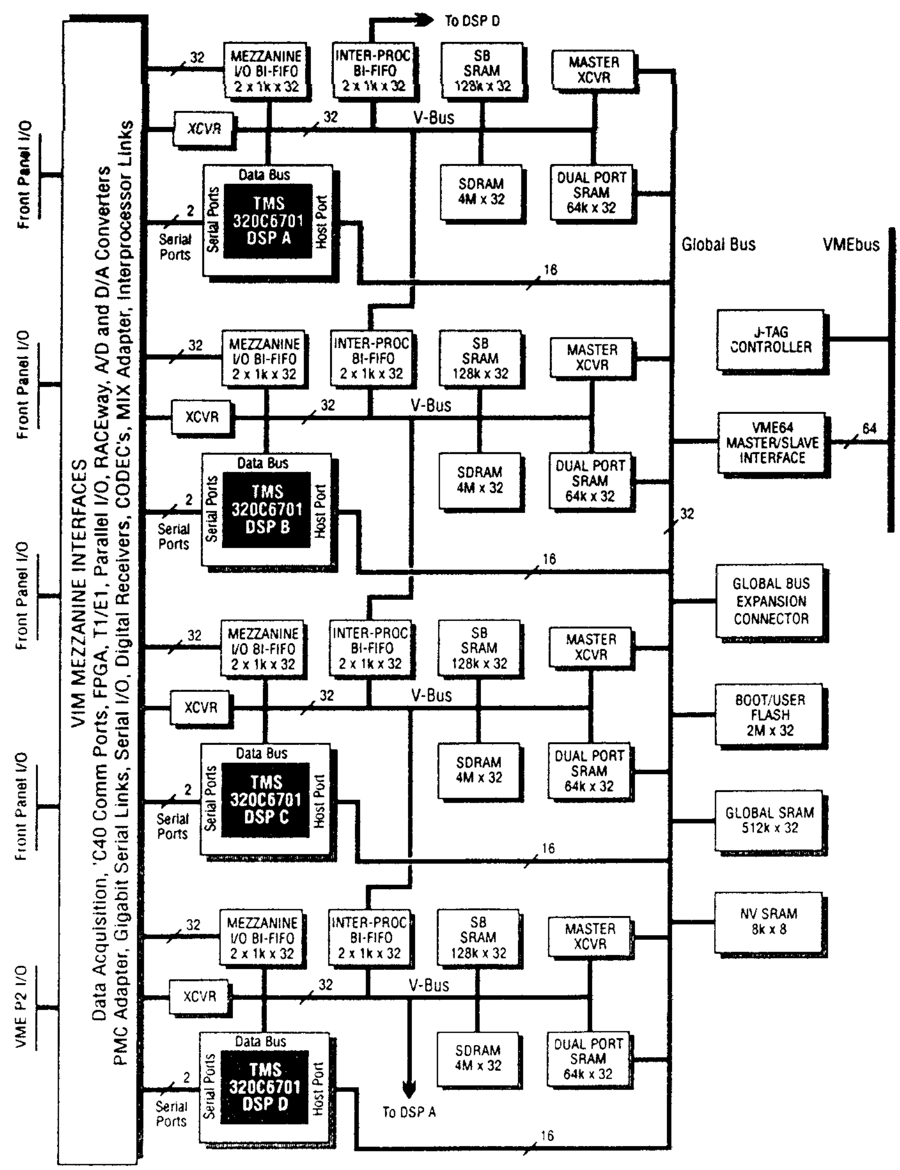
The 4291 is organized as four identical 'C6701 processing nodes, each equipped with several types of I/O and memory resources. This unique architecture has been optimized for handling the most demanding real-time signal processing applications in high-performance VMEbus systems.

Processor Node Memory

Each 'C6701 processor node features three major memory sections: the SB SRAM

[Continued on next page]

Block Diagram, Model 4291



VelociTI ™ is a trademark of Texas Instruments, Inc.

Features

- Four TMS320C6701 floating-point DSP's operating at 167 MHz
- 4 GFLOPS performance
- Memory resources for each processor:
  - 16 MB SDRAM
  - 512 kB zero-wait sync burst SRAM
  - 256 kB dual port SRAM
- I/O resources for each processor:
  - Two serial full-duplex ports for VIM mezzanine I/O
  - Memory access to VIM mezzanine
  - 2 x 1k x 32 bidirectional FIFO for VIM mezzanine board I/O
  - 2 x 1k x 32 bidirectional FIFO for interprocessor communication

More Features on next page...

Conclusion

- Demonstrated linac operation with & without bunch compressor while driving 16 cavities with one klystron
  - reliable & stable operation @ 15 MV/m
- Cavity phasing with spectrometer feasible for phase of vector-sum & cryomod.
  - Individual cavities need to be phased with beam induced transients
- Crosstalk between RF systems (RF Gun ↔ cryomodules) observed
  - No solution to problem yet
- Improved user interface for RF control implemented
- Still a long way to RF Control for use in TESLA tunnel

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