ALPS

SPS BPM Read-out Electronics

RF Front-end – revised

Manfred Wendt

SPS Beam Conditions

	ions	protons
bunch length (4σ)	1.65 ns (14 GeV/c* [FT] or 26 GeV/c*) 4 ns (450 GeV/c*, LHC) 5 ns (400 GeV/c*, FT)	
bunch intensities	>2e9 (min) 5e9 (typ) 2e10 (max)	>2e9 (min) 1.5e10 (max, 5 ns trains) 2.6e11 (max, 25 ns trains) 3.5e11 (max, 50 ns trains)
beam formatting	SB MB trains: up to 6 bunches(?) 50 & 100 ns spacing	SB MB trains: 5 ns: 6…2000 bunches 25 ns: 1…12 batches (up to 288 bunches) or 4 batches, each 80 bunches 50 ns: up to 6 batches (up to 144 bunches)

* beam momentum given for protons,
for ions: 5 GeV/c/u (injection), 177 GeV/c/u (extraction)

BPM Requirements

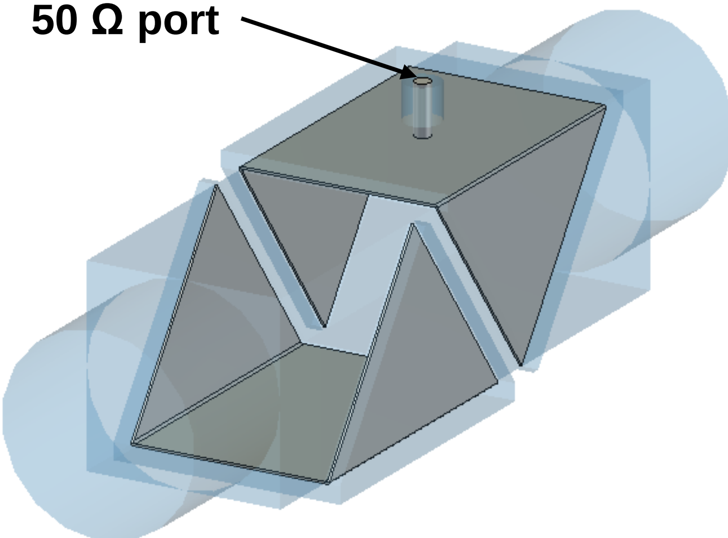
…as relevant for the RF front-end design:

- **TbT and single batch measurement capability**
  - **No SB measurement capability required**
- **BPM operation in TbT and closed-orbit mode under all beam conditions and bunch intensities**
- **Resolution:**
  - **For nominal beam intensities (>2e10 p/bunch):**
    - <400 μm in TbT mode
    - <100 μm in closed-orbit mode (40 turns, ~1 ms)
  - **For low beam intensities (~2e9 p/bunch):**
    - <1 mm in TbT mode
    - <400 μm in closed-orbit mode (40 turns, ~1 ms)
- **Accuracy**
  - **<0.5 mm RMS (including alignment errors)**

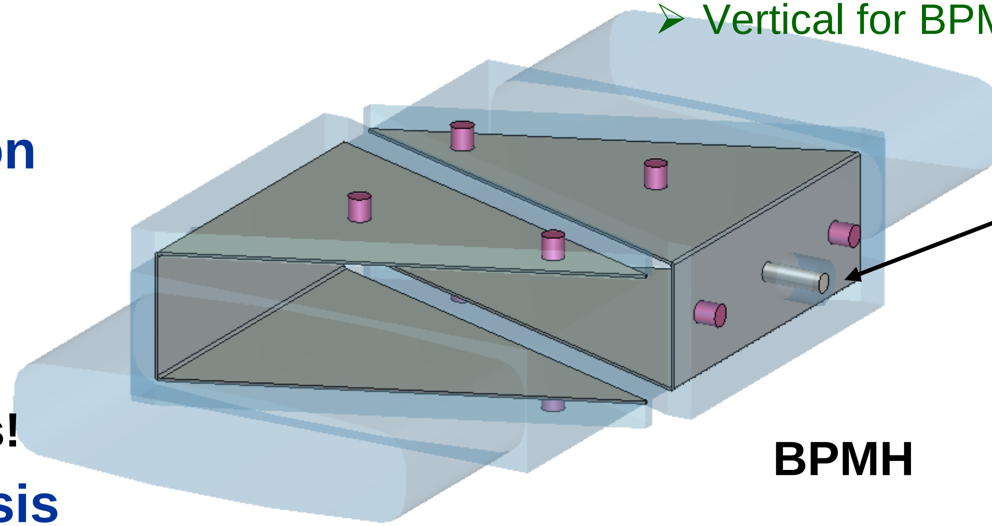
BPM Design ”Boundaries”

- **BPM pickups (”shoe-box” style) stay unchanged**
  - **103x hor. shoebox, 94x vert. shoebox, 19x stripline BPM pickups**
  - **total number of read-out channels: 212 (?)**
- **Omit long coaxial cables**
  - **New ALPS BPM system is based on in-tunnel front-end electronics**
- **SPS Tunnel environment**
  - **Radiation tolerant components!**
- **Keep conceptual design of the RF front-end prototype**
  - **Based on logarithmic RF amplifiers (for dynamic range compression)**
  - **Successful operation in the AWAKE beam-line**
  - **BUT: Needs modifications to fully cover all SPS beam conditions**
- **Tight time schedule and tight budget!**

”Shoe-box” Pickup Signal Analysis

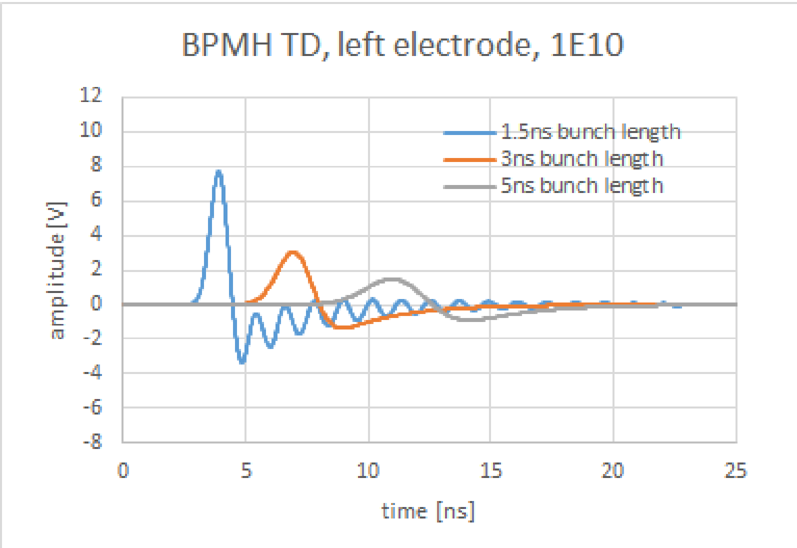


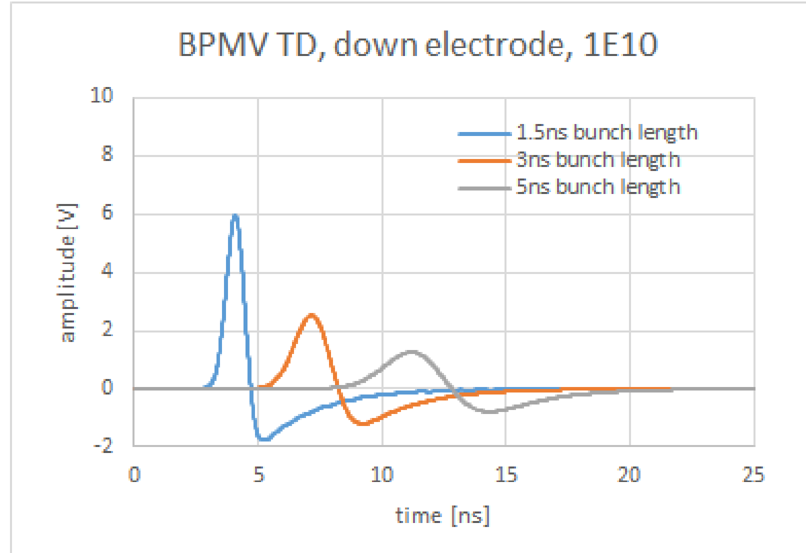
- **Single bunch**
  - **1e10 protons, 450 GeV**
    - “pencil” beam
  - **σ = 1.5 ns, 3 ns, 5 ns**
    - 1 ns results also available
  - **5 mm beam offset**
    - Horizontal for BPMH
    - Vertical for BPMV

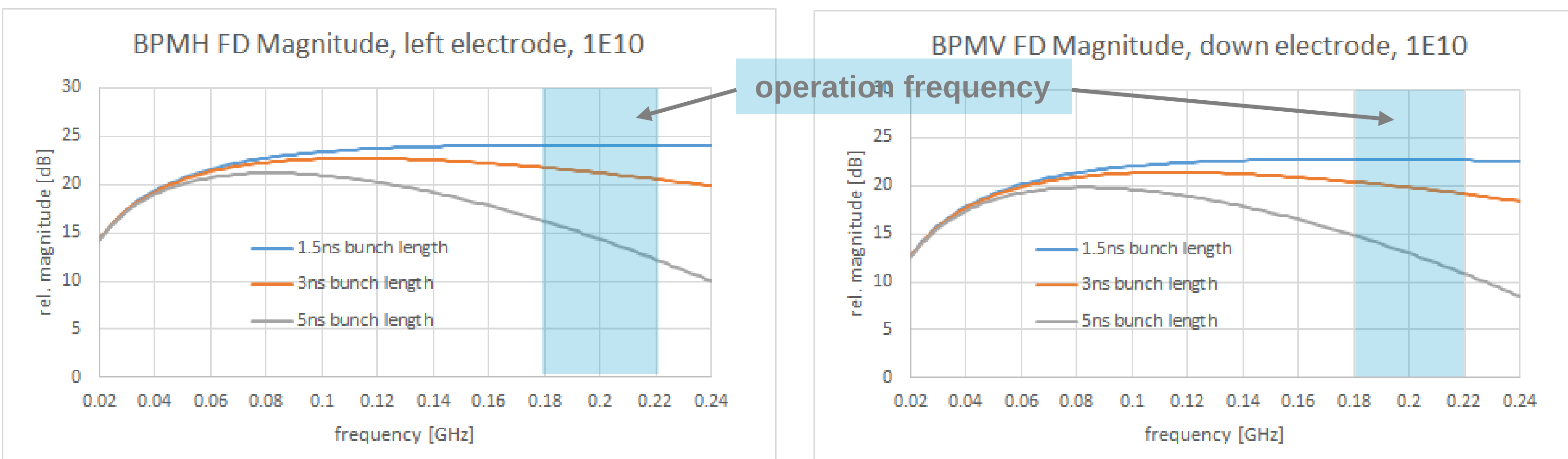


- **Wakefield simulation**
  - **DC…2 GHz**
  - **~850K mesh cells**
  - **Accuracy -40 dB**
  - **Perfect 50 Ω ports!**
- **Time domain analysis**
  - **2-port S-parameters**

Single Bunch Response

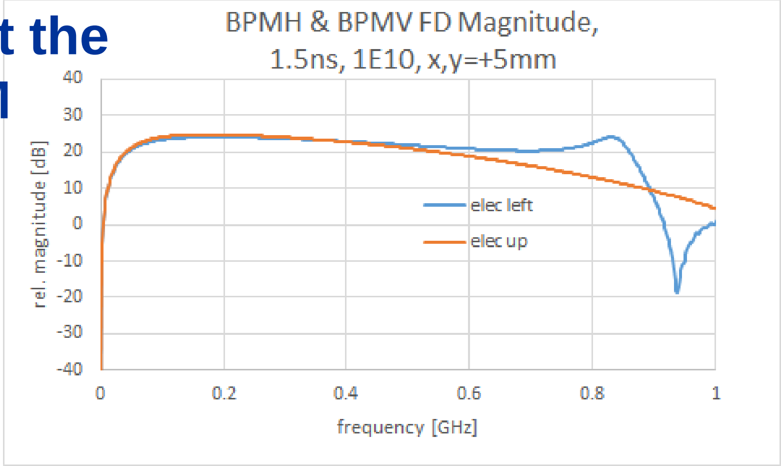




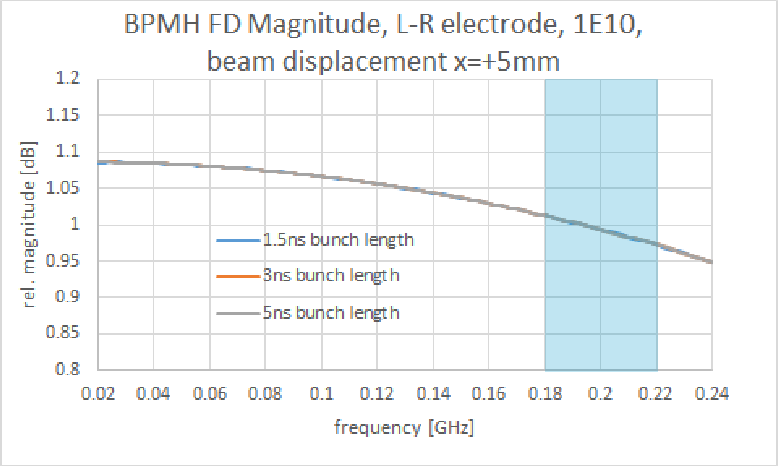


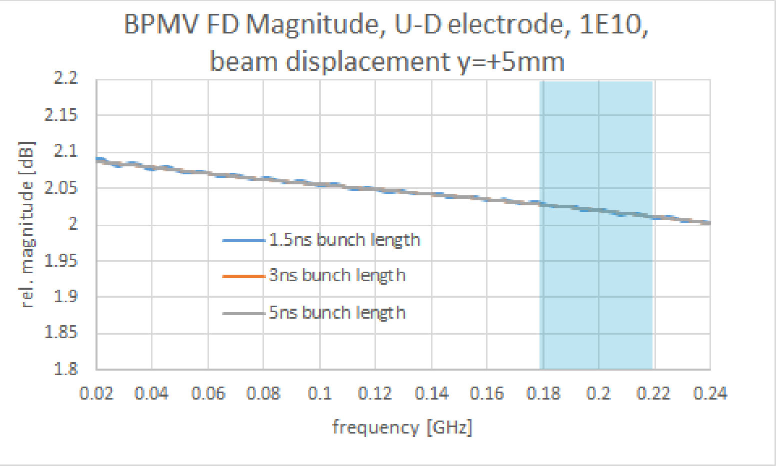
”Shoe-box” BPM Position Sensitivity

- **Transfer response is almost the same for hor. and vert. BPM**
  - ***f* < 500 MHz**



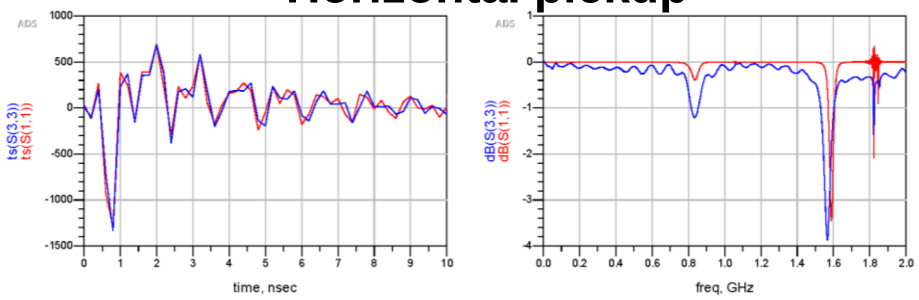
- **horizontal: ~0.2 dB/mm**
  - **~2.3 % change in voltage signal**
- **vertical: ~0.4 dB/mm**
  - **~4.7 % change in voltage signal**
- **independent of the bunch length**

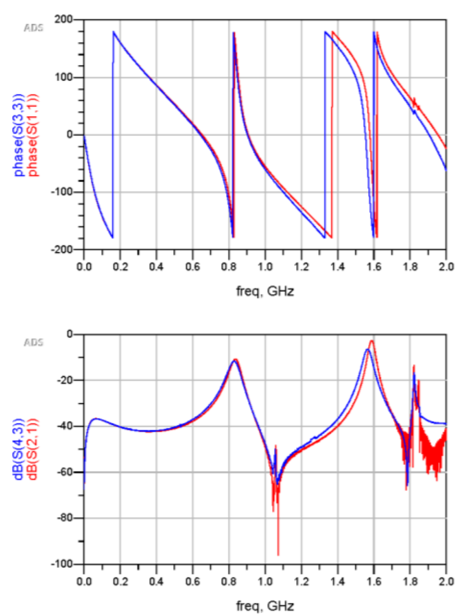


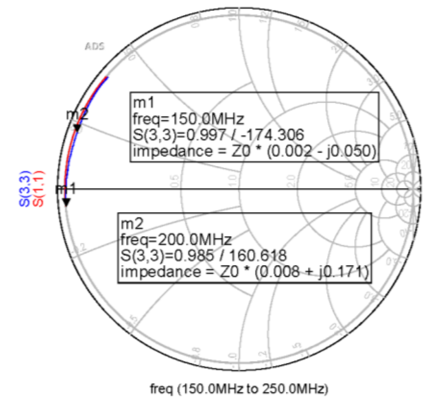


"Shoe-box" BPM Electrical Analysis

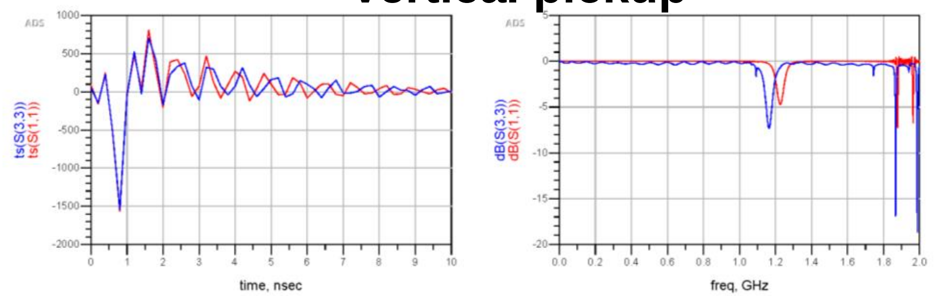
Horizontal pickup

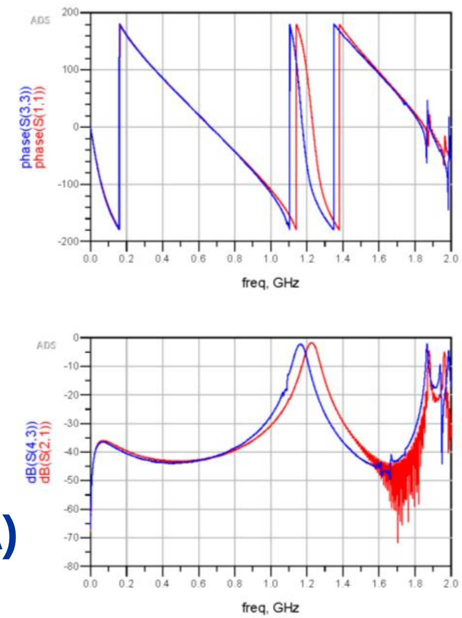


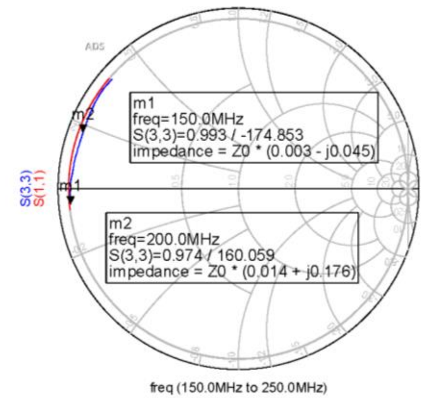




Vertical pickup





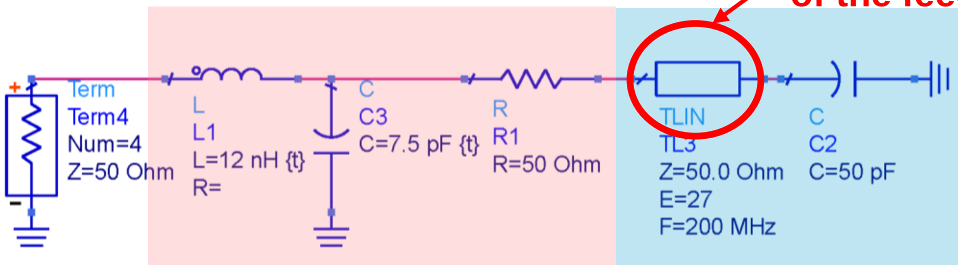


Measurement (VNA)

Simulation (CST)

”Shoe-box” BPM Source Impedance

transmission-line effect of the feedthrough



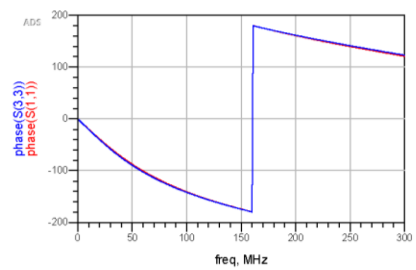
BPM equivalent circuit (up to ~500 MHz)

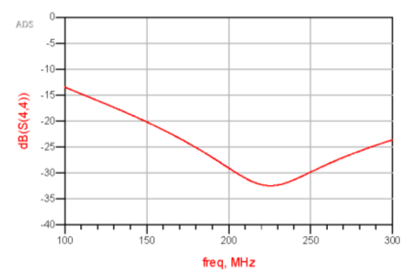
50 Ω matching network (~100…300 MHz)

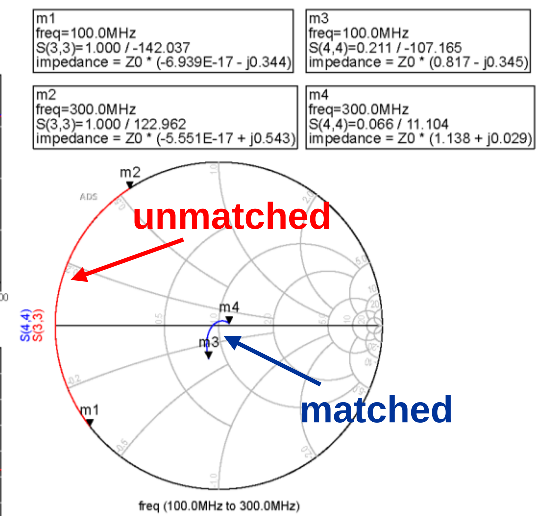
∠S11 measured

∠S11 equivalent circuit

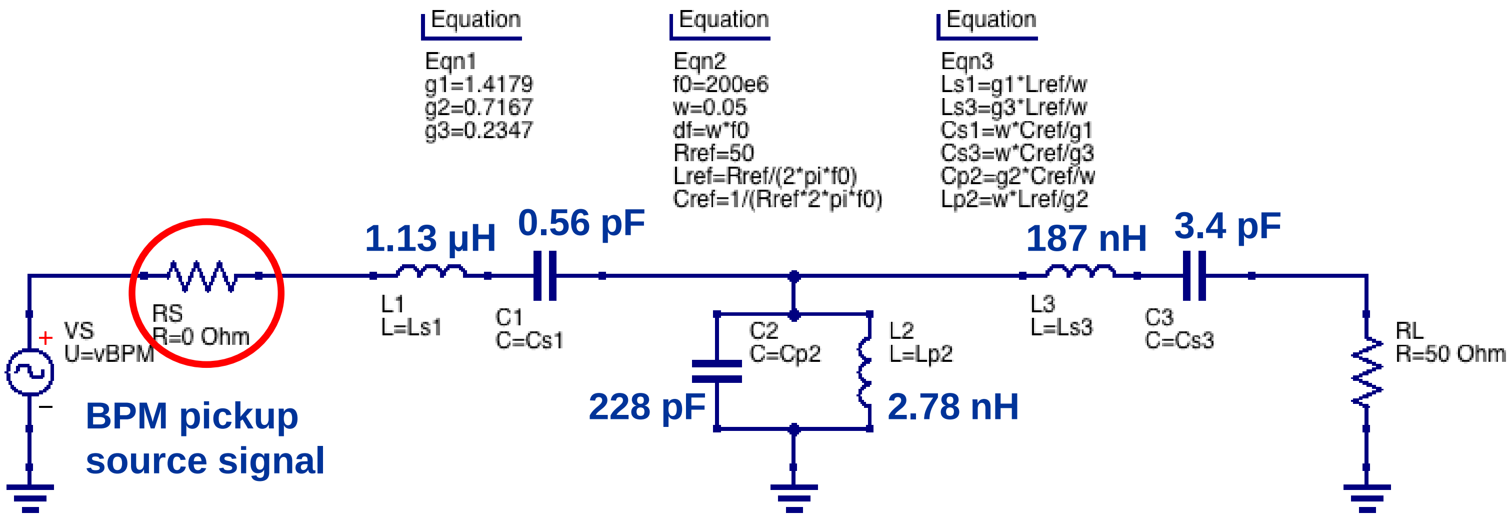
Because the original idea of a single terminated BPF did not materialize!





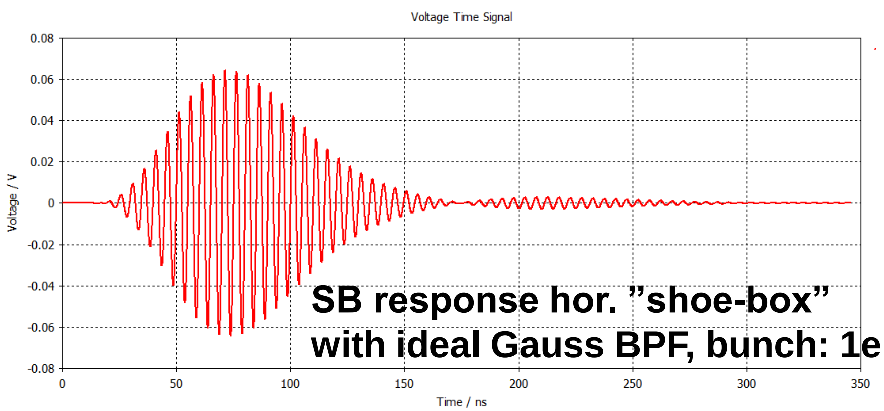


Fun with Filters



Ideal single terminated 3rd-order Gauss BPF

f_0 = 200 MHz, BW = 10 MHz

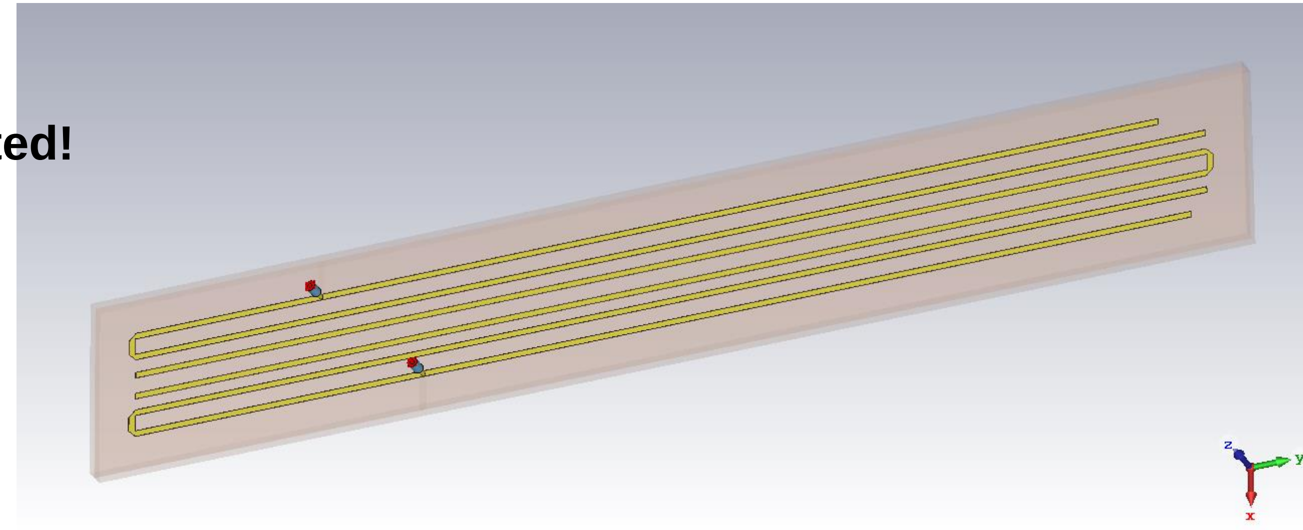


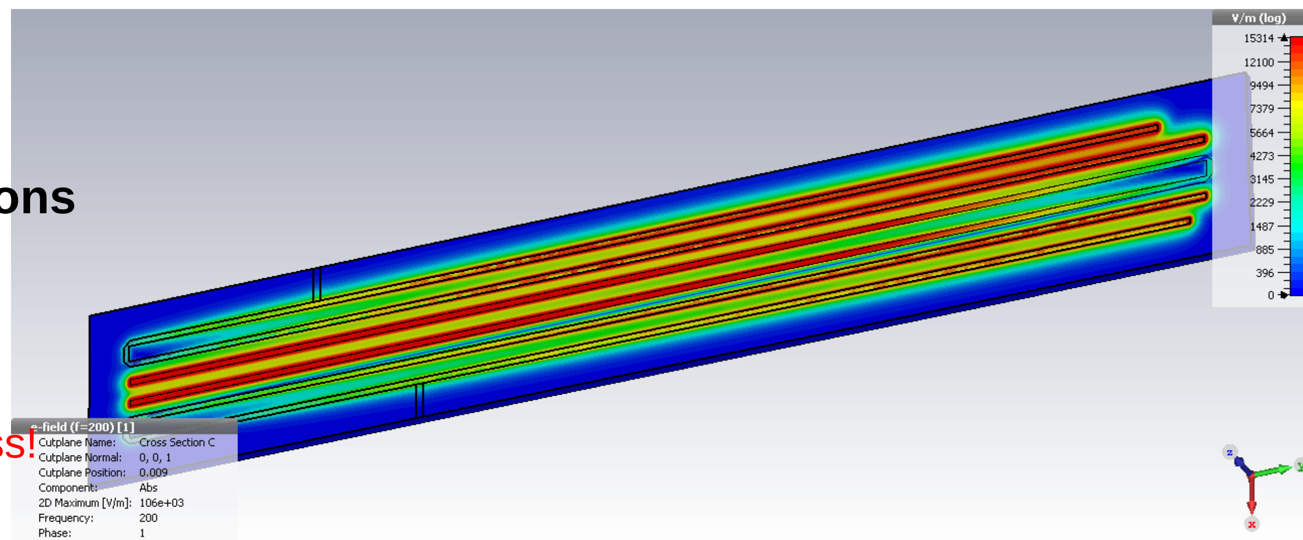
SB response hor. "shoe-box" with ideal Gauss BPF, bunch: 1e10, 5 ns

- **No losses due to resistive impedance matching elements!!!**
- **BUT: impossible to implement as distributed elements filter network!**

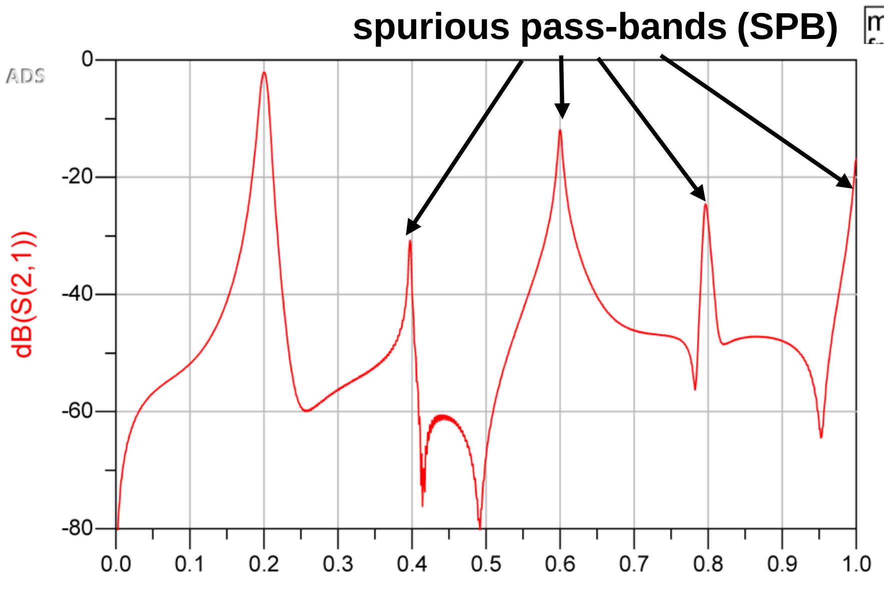
Gaussian Band-pass Filter (BPF)

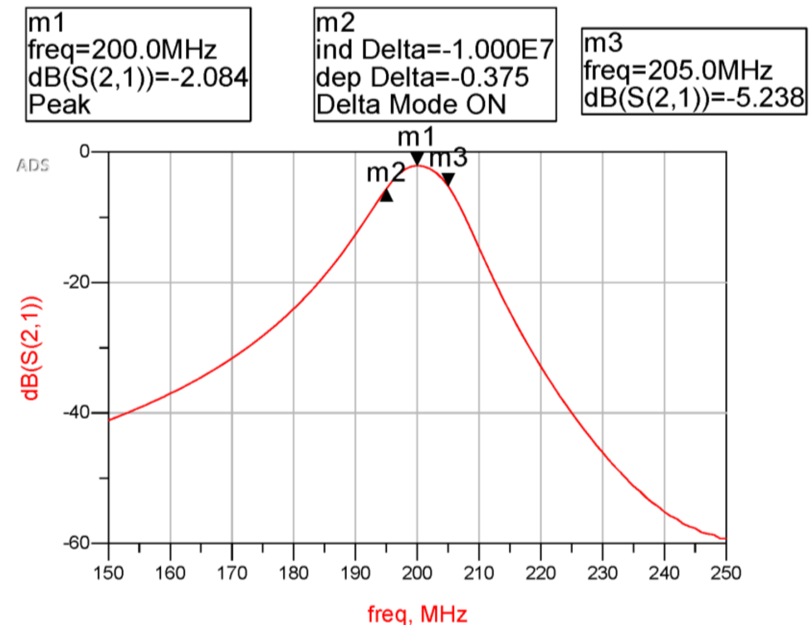
- **3rd-order Gaussian**
  - **Not too complicated!**
- **f_0 = 200 MHz, BW = 10 MHz**
  - **Compromise for the SB response**
- **"Hairpin" design**
  - **Rather compact**
  - **$(n_{odd})xf_0$ SPB**
  - **"reasonable" strip-line dimensions**
  - **strip-line PCB**
    - tolerances, costs
    - BUT: 2 dB insertion loss! (no free lunch!)

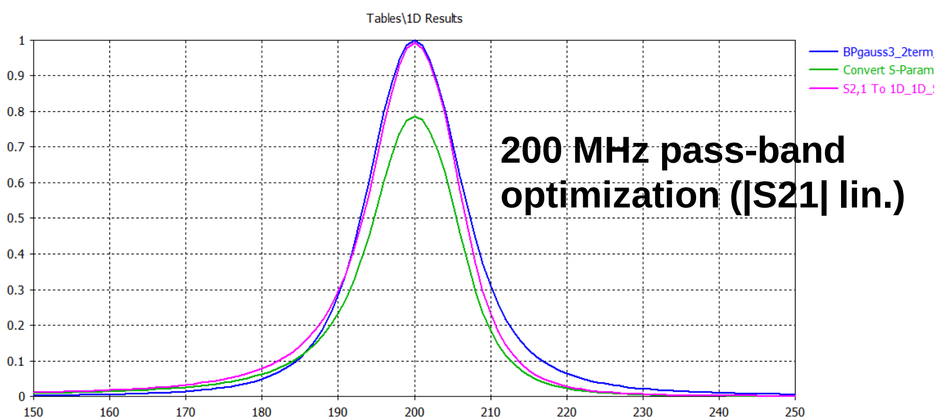


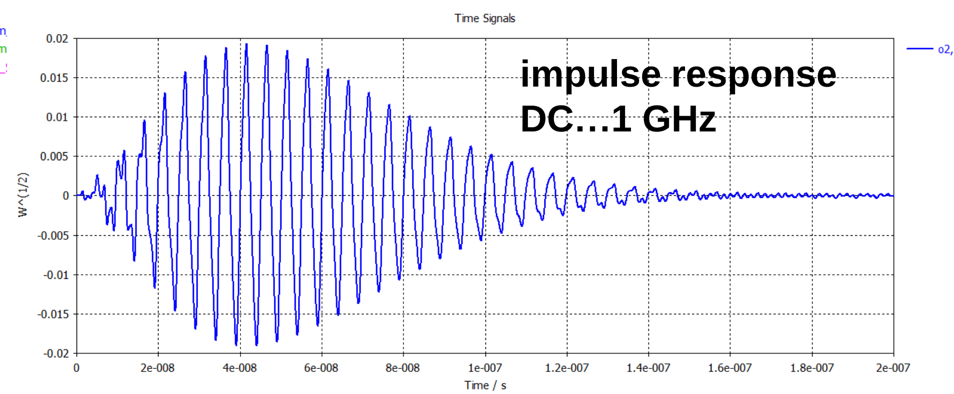


3rd- order Gaussian BPF Response



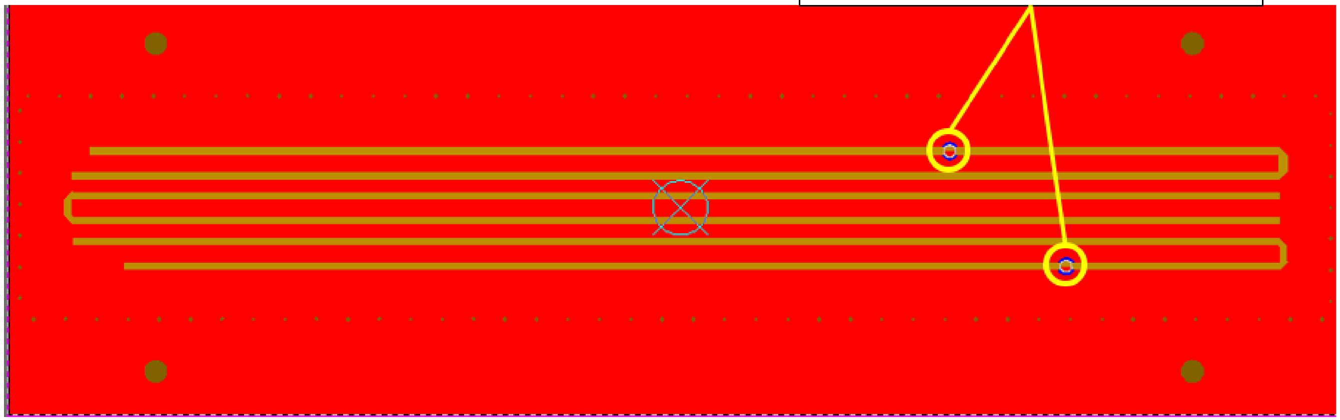






Gerber Files and Manufacturing Quote

Blind vias: Top to middle layer



All other vias are grounded through vias!

s r.o.

5 01 Mělník

x : 315 671 495

IČ : 46710311

CERN, Finance Division
Lars Oskar Bjorkqvist
CH-1211 GENEVA 23
Schweiz

Telefon : +41 22 767 6257

QUOTATION

Order Number : e-mail

Order No : 172344

Name		Format	Date	Price	Quantity	In Total	
Manfred_filter	3-layer Au	0,53 x 1,70	25.10.2017	23,92	10	239,20	EUR
Data preparation			25.10.2017	38,86	1	38,86	

Prices are without VAT — In Total : 278,06 EUR

lead time 2 weeks

Please send us the order by email to: printed@printed.cz

Tel : 00420 315 670 137

Fax : 00420 315 671 495

Delivery Date : 25.10.

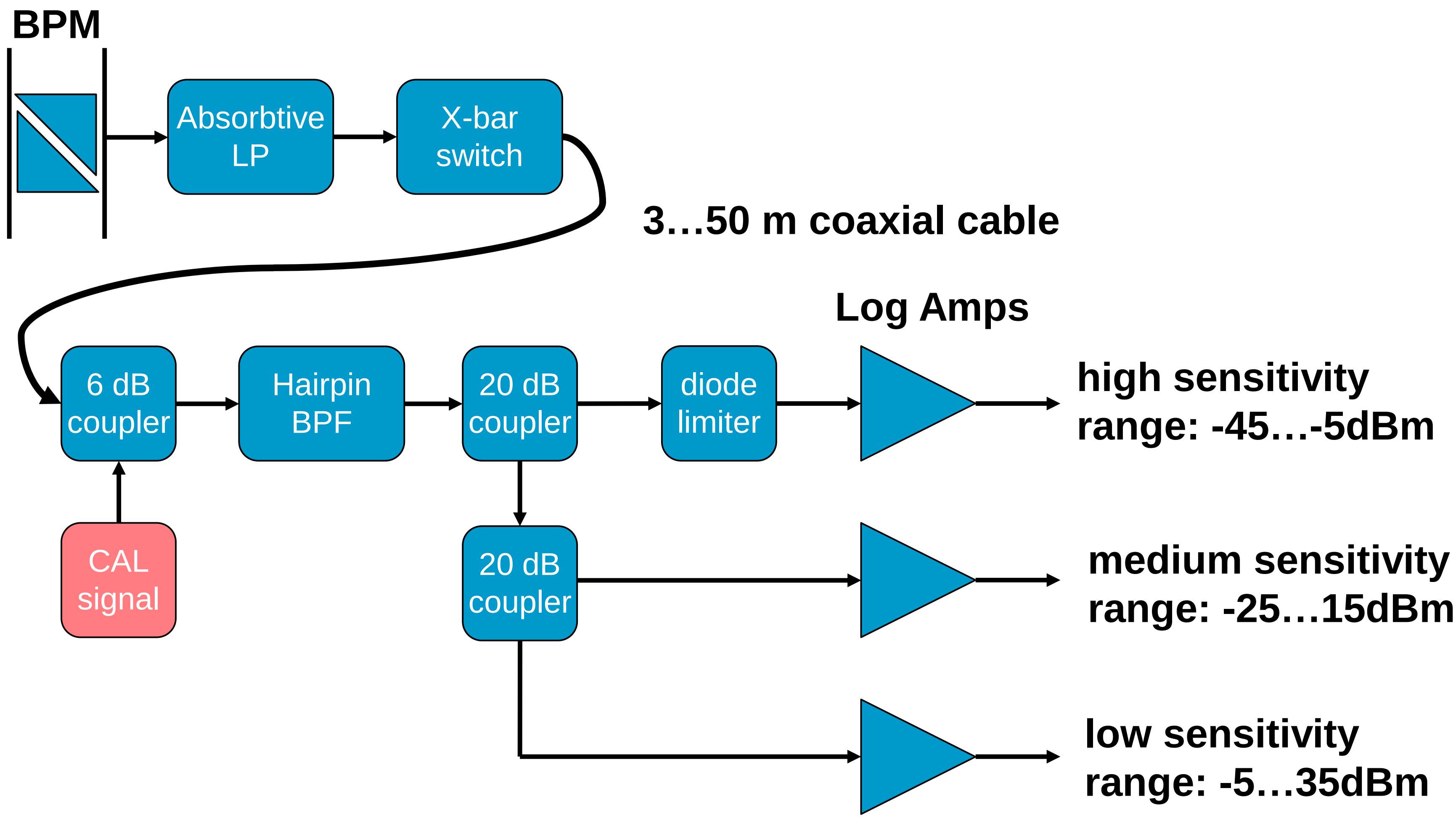
Transport : spedition

Procening Day : 11.10.2017 Mělník — Handle : Svobodová Ilona

The production will be started after this quotation confirmation or recieving the order.

Thanks to the help of *Oskar Bjorkqvist*

ALPS RF Frond-end Layout (1 Ch.)



ADL5519 Logarithmic Amplifier

- **Dual LogAmp ADL5519**
  - **2-ch LogAmp**
    - Rare!
  - **Broadband**
    - However, not required…
  - **Integrated OpAmps**
  - **Dynamic range**
    - 62 dB at 3 dB error
    - 50 dB at 0.5 dB error
    - 40 dB at ~0.1 dB error
      -45…-5 dBm intensity range
      (3.56…356 mVpp)
  - **~ 50dBm sensitivity**
    - ~2mVpp (0.5 dB error)

1 MHz to 10 GHz, 62 dB Dual Log Detector/Controller

ADL5519

FUNCTIONAL BLOCK DIAGRAM

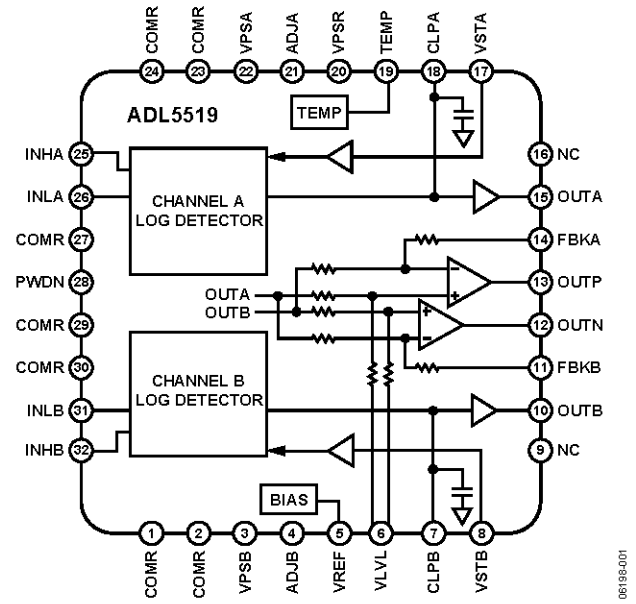


Figure 1.

ADL5519 Performance @ 100 MHz

TYPICAL PERFORMANCE CHARACTERISTICS

V_P = 5 V; T_A = +25°C, −40°C, +85°C; CLPA, CLPB = 1 µF. Colors: +25°C black, −40°C blue, +85°C red.

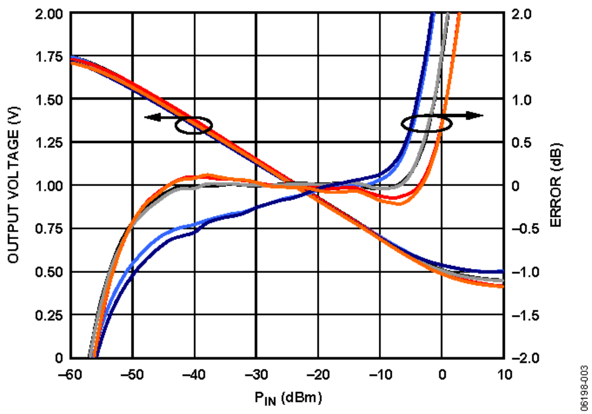


Figure 3. OUTA, OUTB Voltage and Log Conformance vs. Input Amplitude at 100 MHz, Typical Device, ADJA, ADJB = 0.65 V, 0.7 V, Sine Wave, Single-Ended Drive

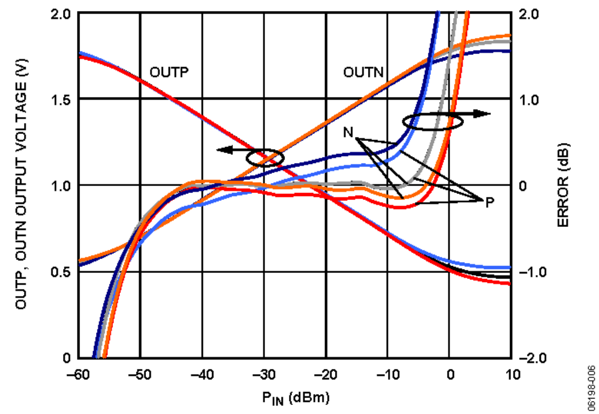


Figure 6. OUTP, OUTN Gain Error and Voltage vs. Input Amplitude at 100 MHz, Typical Device, ADJA, ADJB = 0.65 V, 0.7, Sine Wave, Single-Ended Drive, P_{INHB} = −30 dBm, Channel A Swept

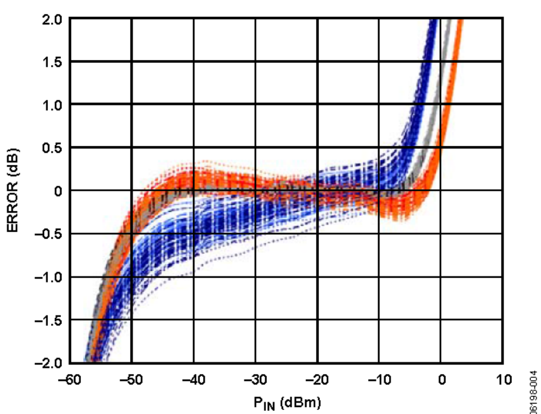


Figure 4. Distribution of OUTA, OUTB Error over Temperature After Ambient Normalization vs. Input Amplitude for 45 Devices, Frequency = 100 MHz, ADJA, ADJB = 0.65 V, 0.7 V, Sine Wave, Single-Ended Drive

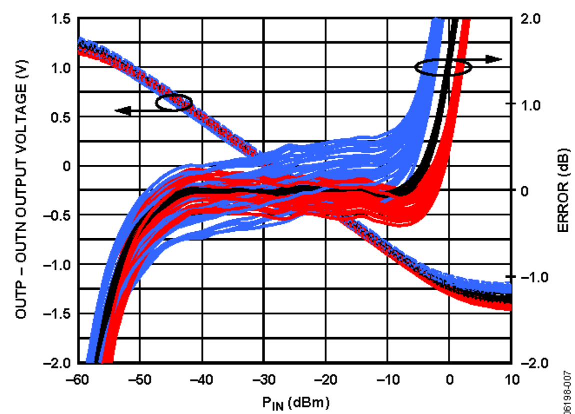
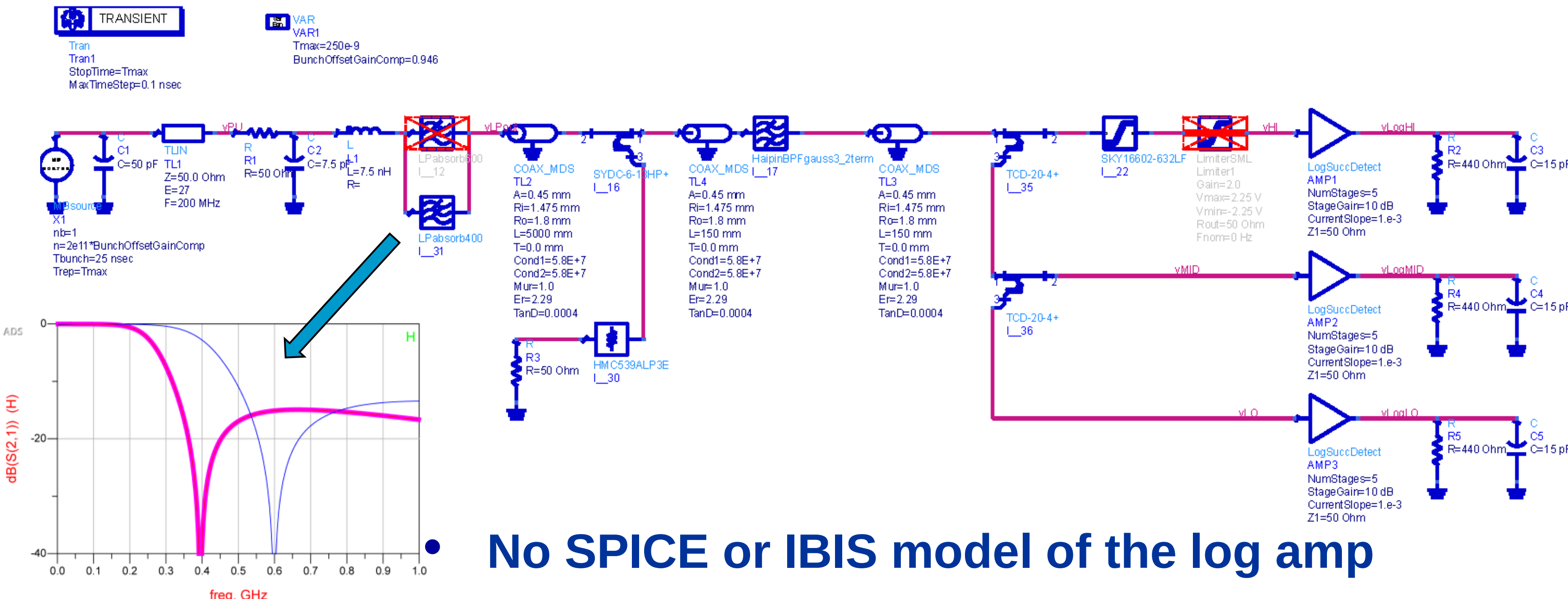


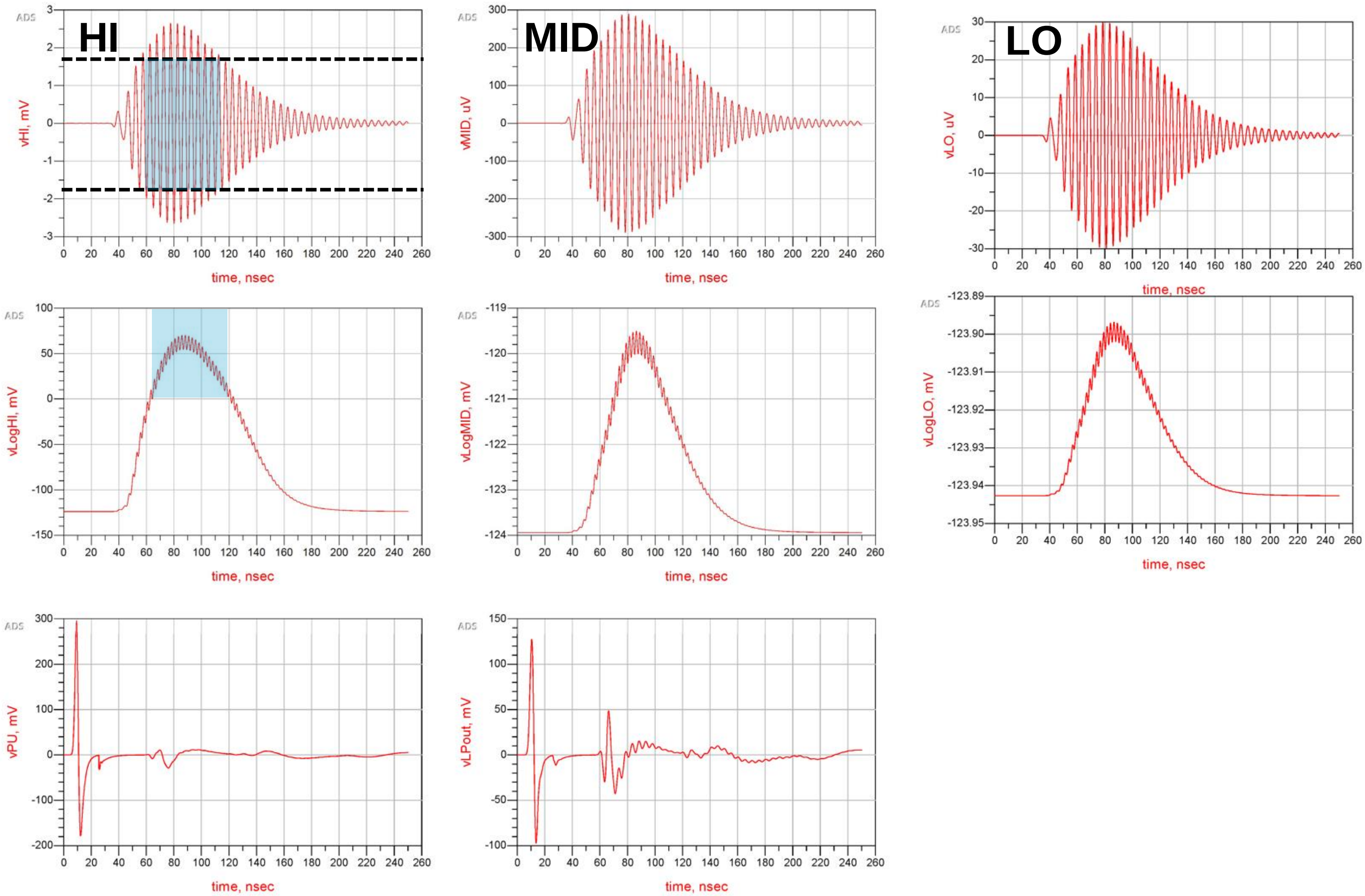
Figure 7. Distribution of [OUTP – OUTN] Gain Error and Voltage vs. Input Amplitude over Temperature, After Ambient Normalization for 45 Devices from a Nominal Lot, Frequency = 100 MHz, ADJA, ADJB = 0.65 V, 0.7 V, Sine Wave, Single-Ended Drive, P_{INHB} = −30 dBm, Channel A Swept

RF Front-end PU Signal Simulations

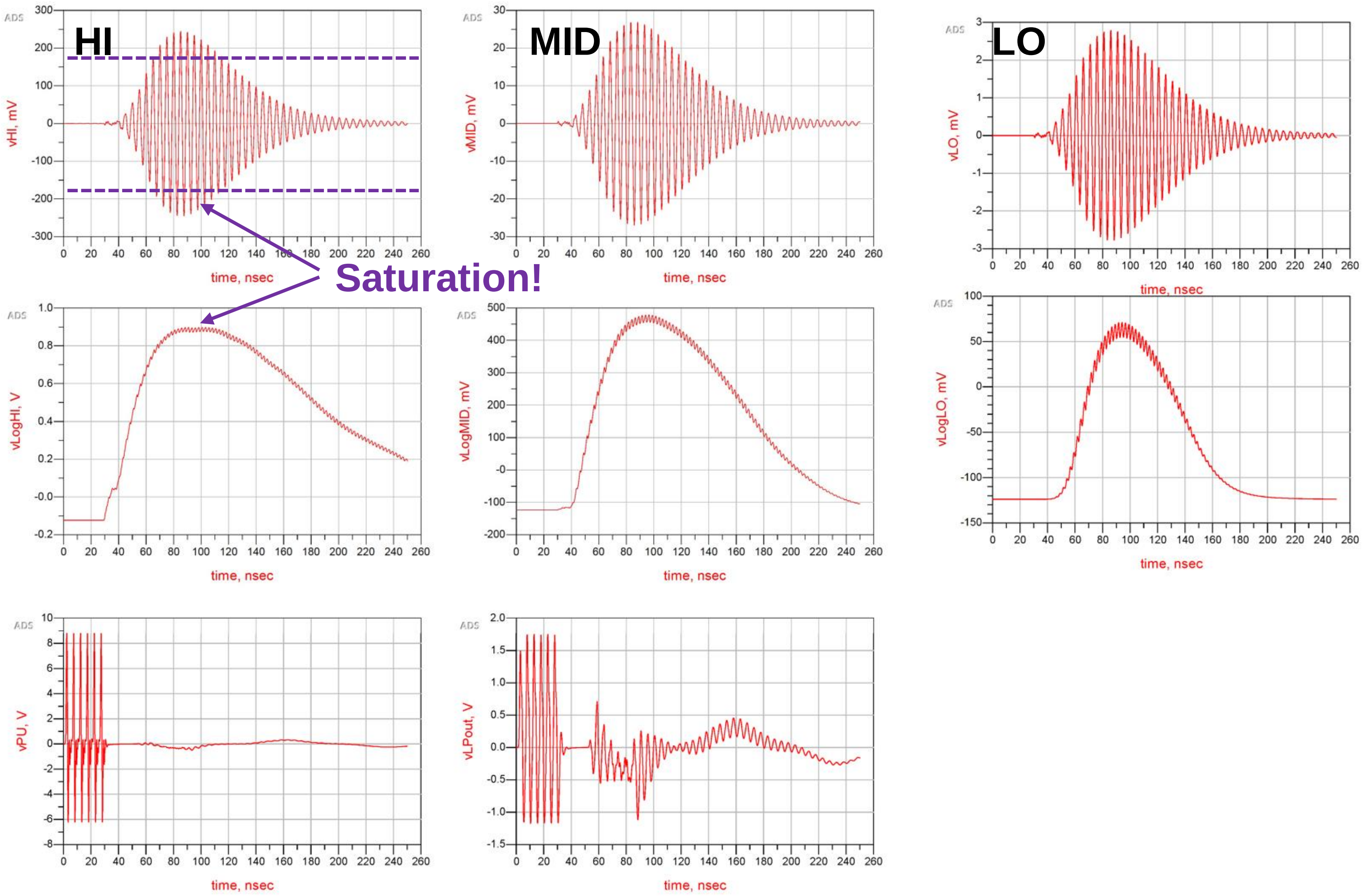


- **No SPICE or IBIS model of the log amp**
  - **Simplistic model used, tweaked to match the ADL5519 characteristics**
- **Included RF loss effects of materials**
  - **Here with 5m long RG58 between pickup and FE**
- **Absorptive low-pass filter**
  - **Here simulated with 400 MHz pole**

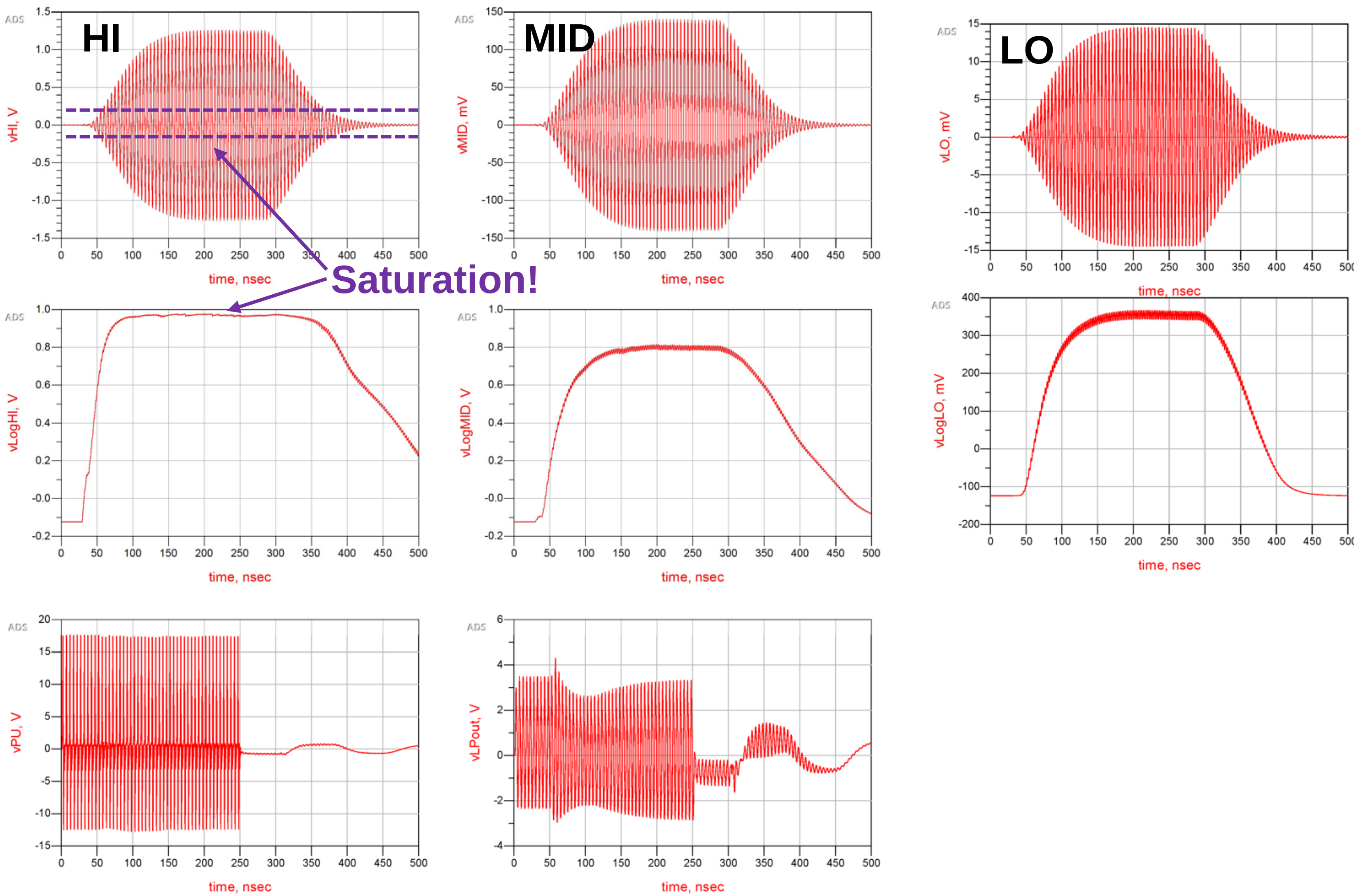
SB: 5ns, 2e9


HI
MID
LO
vHI, mV
vMID, uV
vLO, uV
vLogHI, mV
vLogMID, mV
vLogLO, mV
vPU, mV
vLPout, mV
time, nsec
ADS

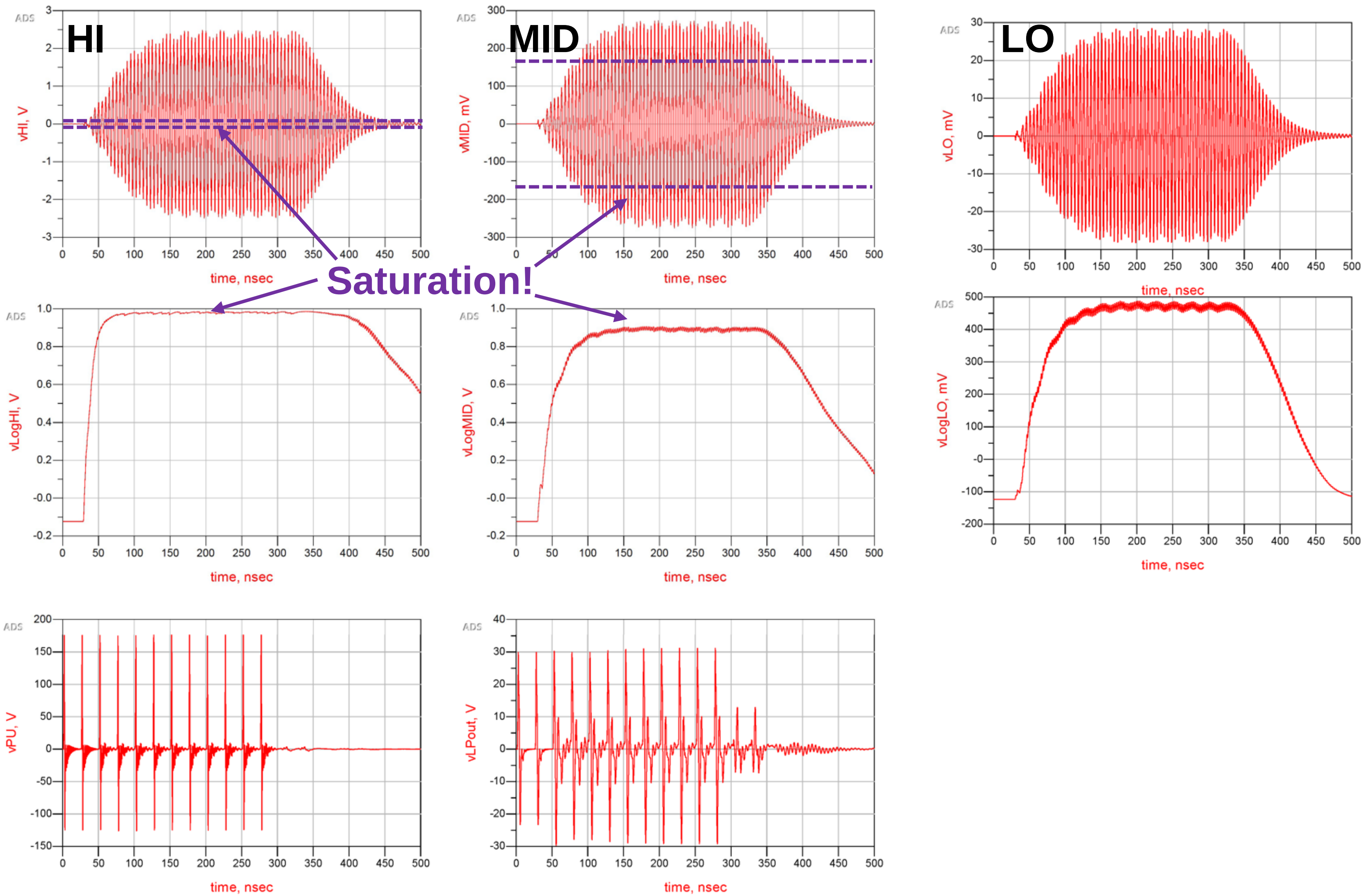
MB: 6 bunches, 5ns spacing: 1.5ns, 1e10



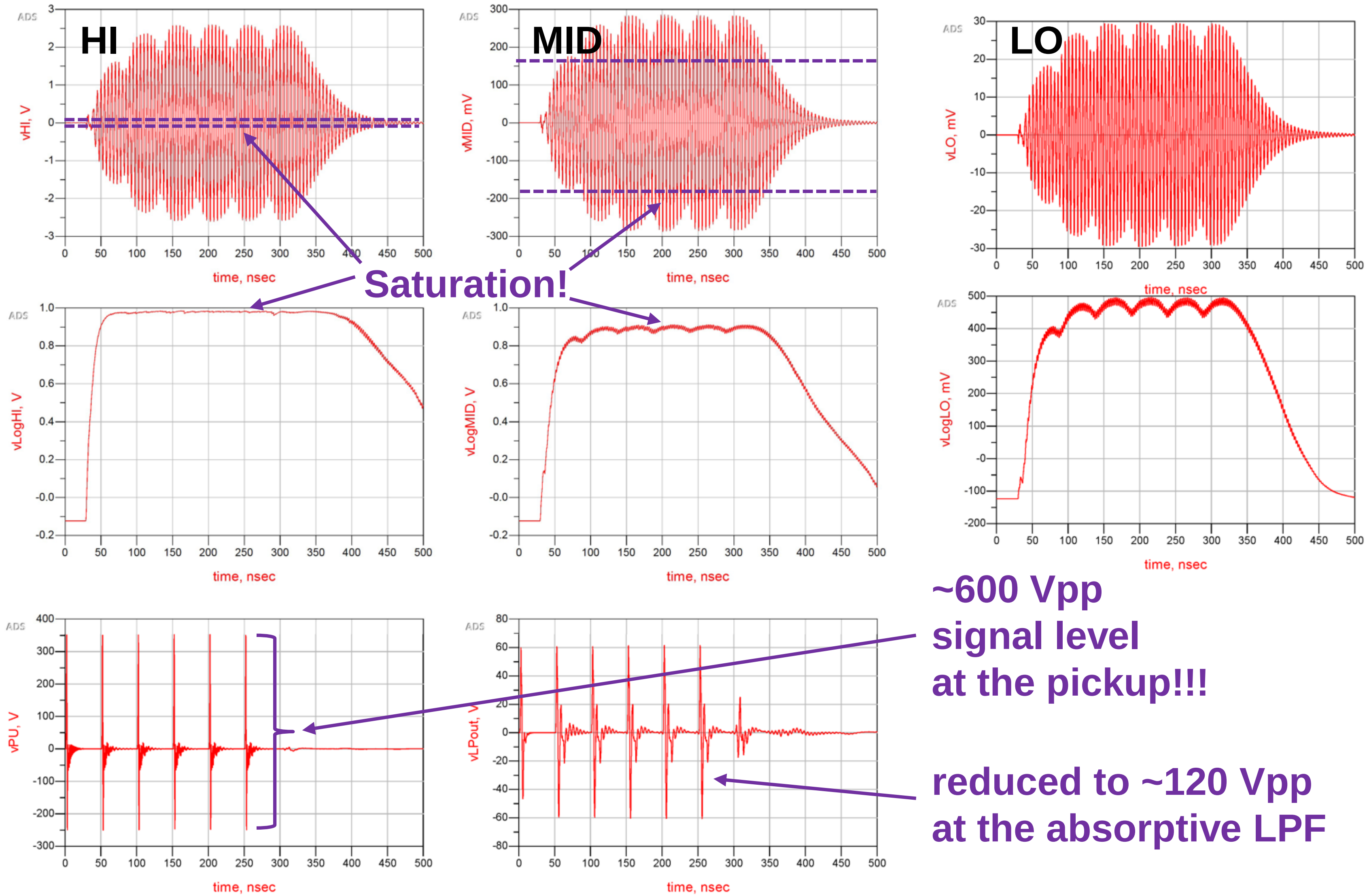
MB: 50 bunches, 5ns spacing: 1.5ns, 2e10



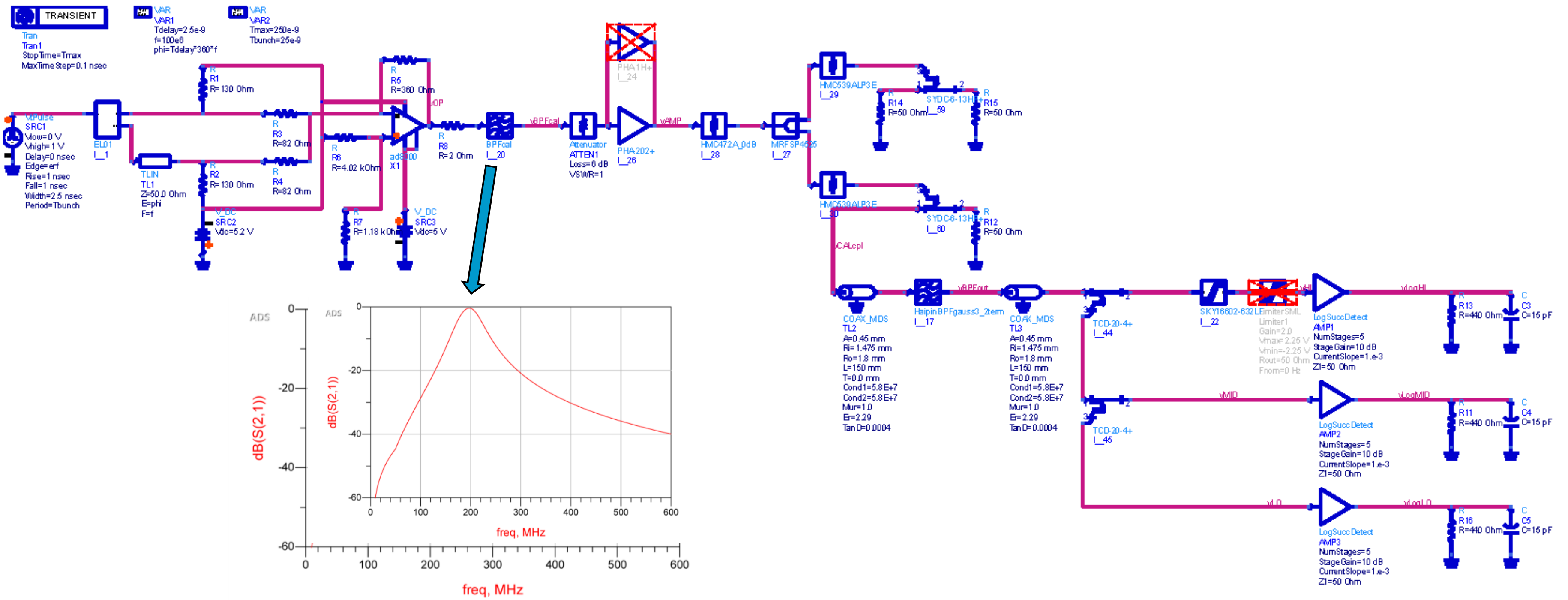
MB: 12 bunches, 25ns spacing: 1.5ns, 2e11



MB: 6 bunches, 50ns spacing: 1.5ns, 4e11

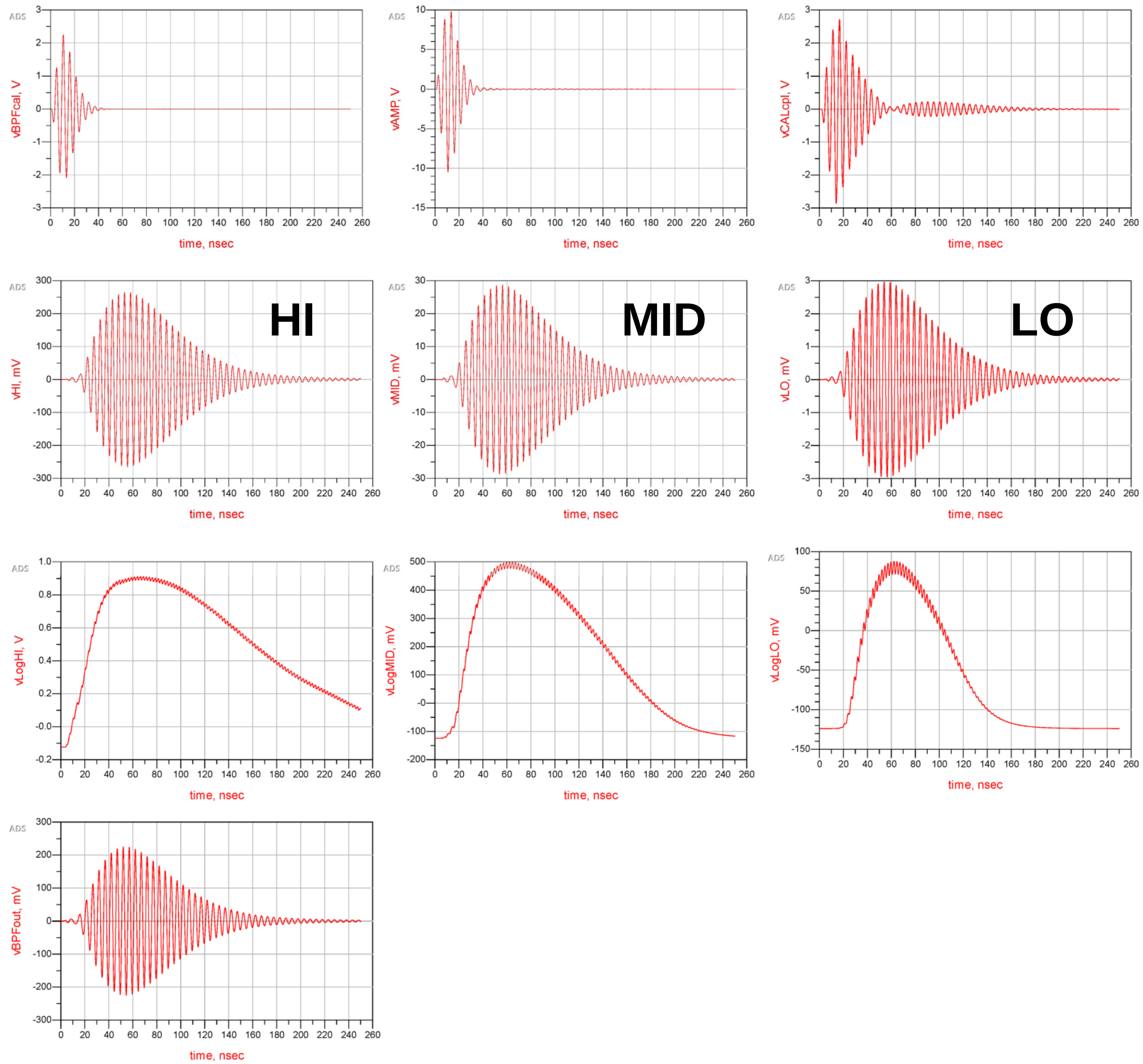


CAL Signal Simulations

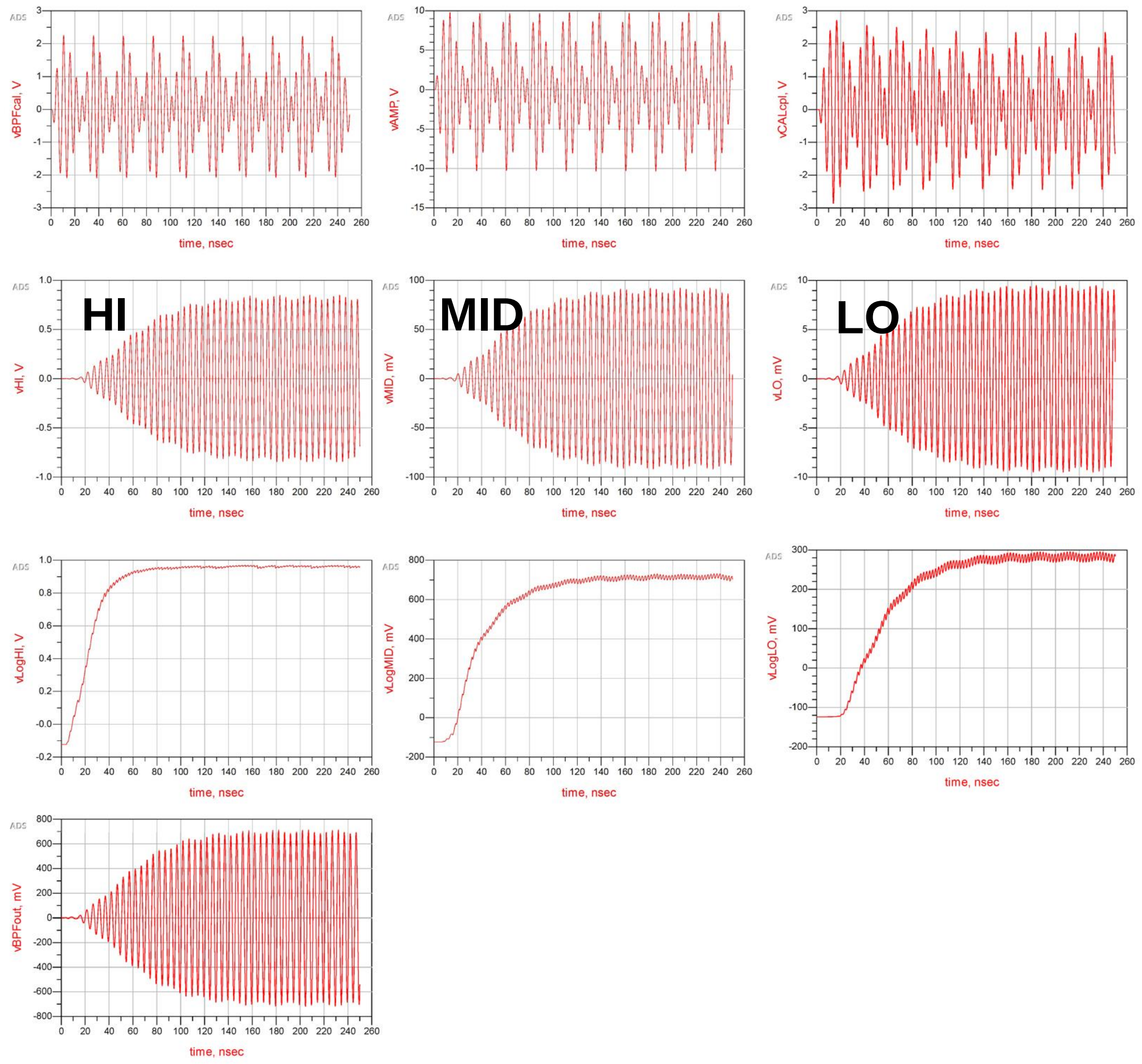


- **Calibration scheme based on 25 ns pulses**
  - **utilizes a 200 MHz, BW 40 MHz broadband Gaussian BPF to improve the CAL signal energy efficiency in the pass-band**
- **GaAs step attenuator schema**
  - **31 dB / 0,5 dB steps for beam / bunch intensity**
  - **2x 8 dB / 0.25 dB steps for beam displacement**

SB CAL Signal, 0 dB ATT



SB CAL Signal, 0 dB ATT



Last Slide

- **Radiation test of new semiconductor components**
  - **All new components are pHEMT GaAs technology, still need to be qualified!**
    - Evaluation boards available!
- **A few design details need to be finished**
  - **Include anti-aliasing LPF to the outputs**
  - **Add level shifters to control the step attenuators**
  - **Check *Guerilla* alternative for *Mini-Circuits* CAL RF amp**
    - Lower noise, lower power consumption, power off capability
  - **Check DC power consumption**
  - **Check voltage and power on critical components**
    - avoid overheating of components!
  - **Verify stripline pickup signal levels**
- **Verify design choices**
  - **~20 dB overlapping log amp ranges**
  - **no linear pre-amplifier for high sensitivity range**