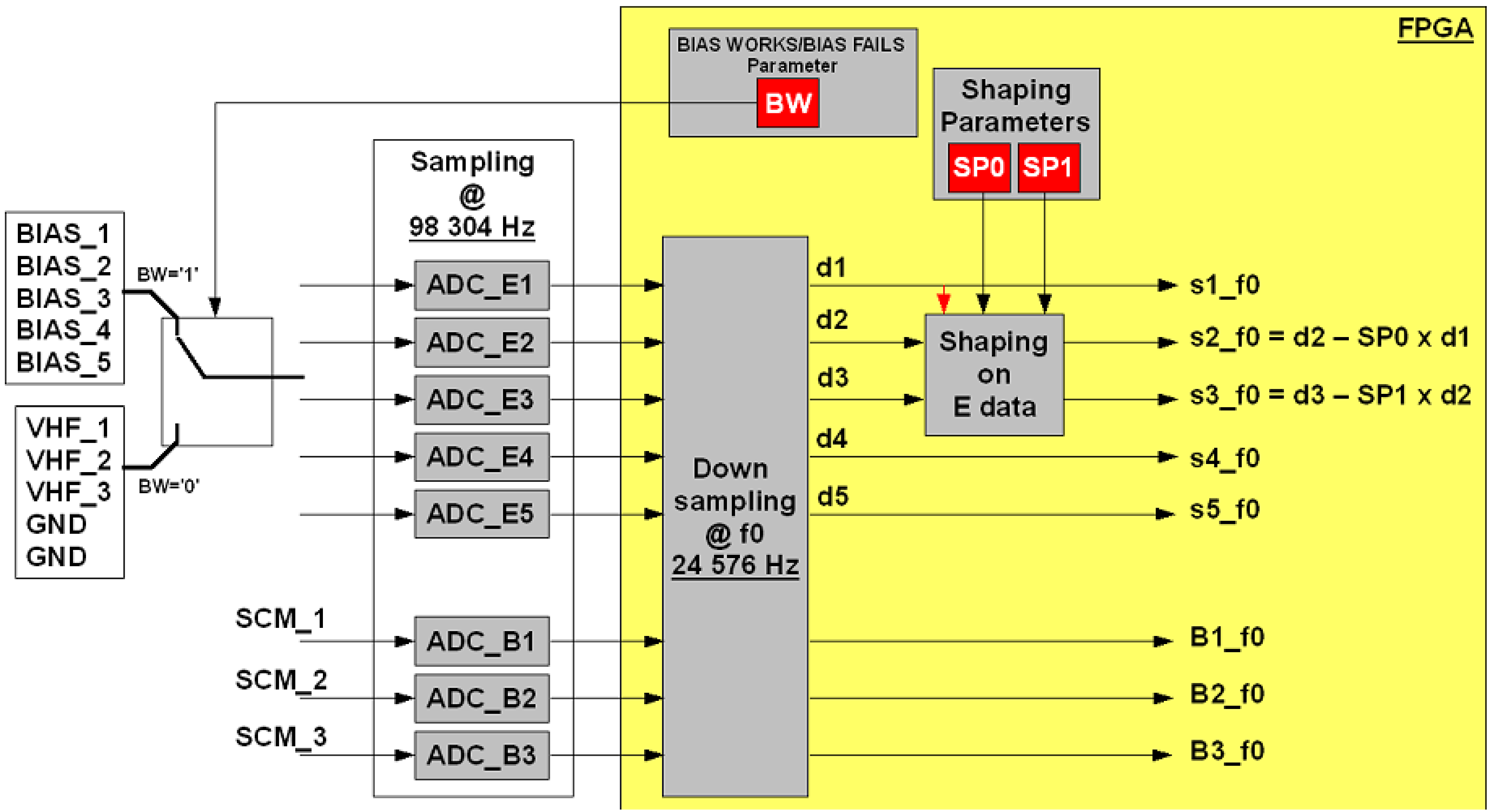
LFR calibration status

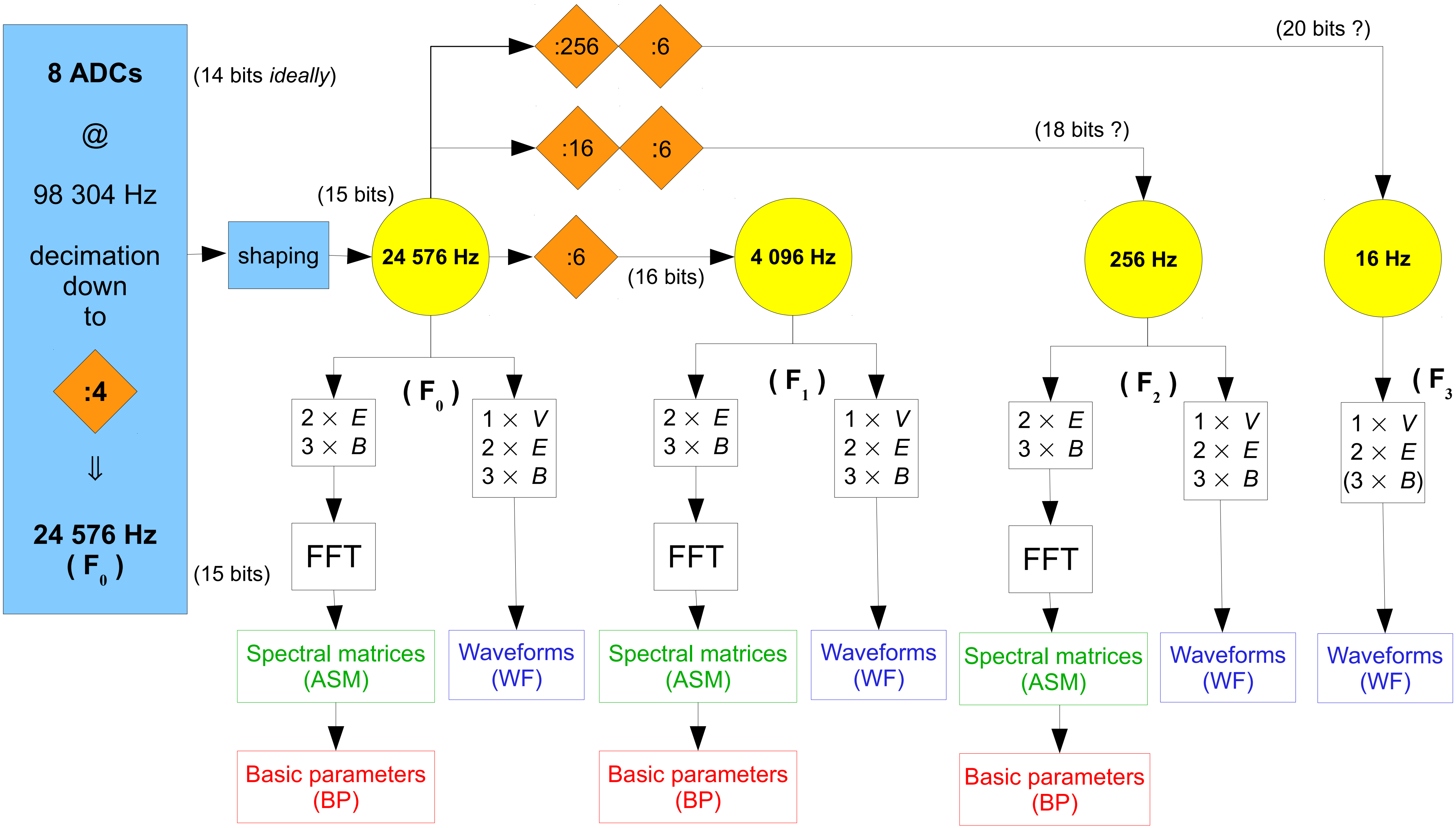
- Delta calibration : presently nothing (coming soon ?)
- Standalone calibration : new insight from simulation **(good benchmark)**
- Background levels (few spectra)

Thomas Chust and the LFR team

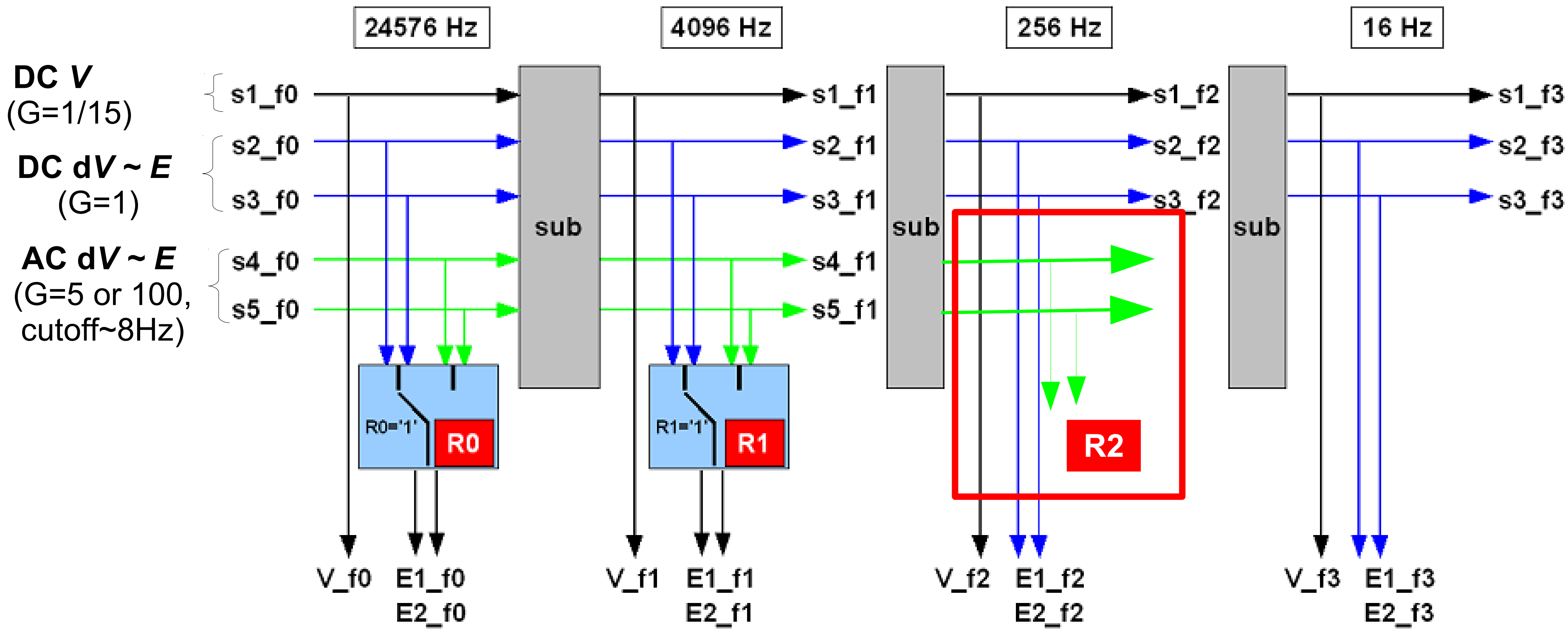
LFR 11 analogue inputs



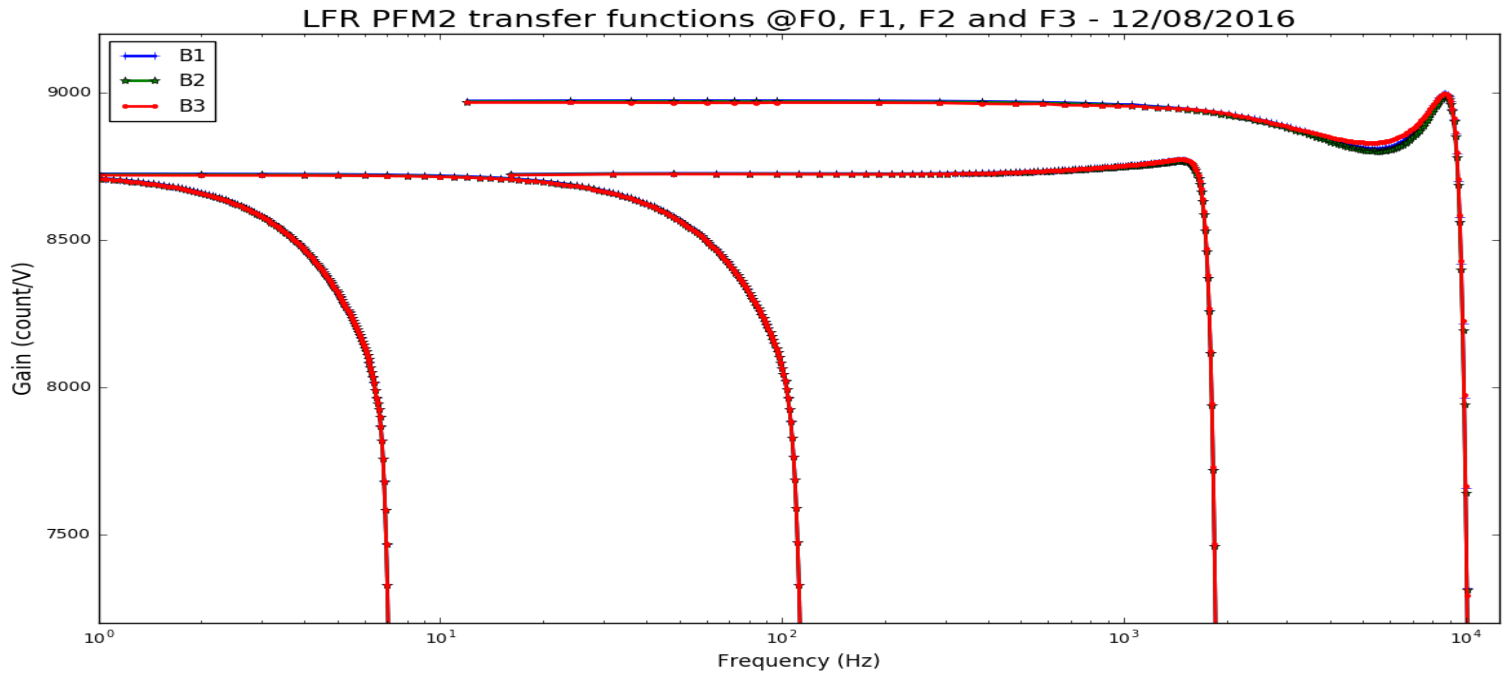
LFR Decimation and Processing Strategy

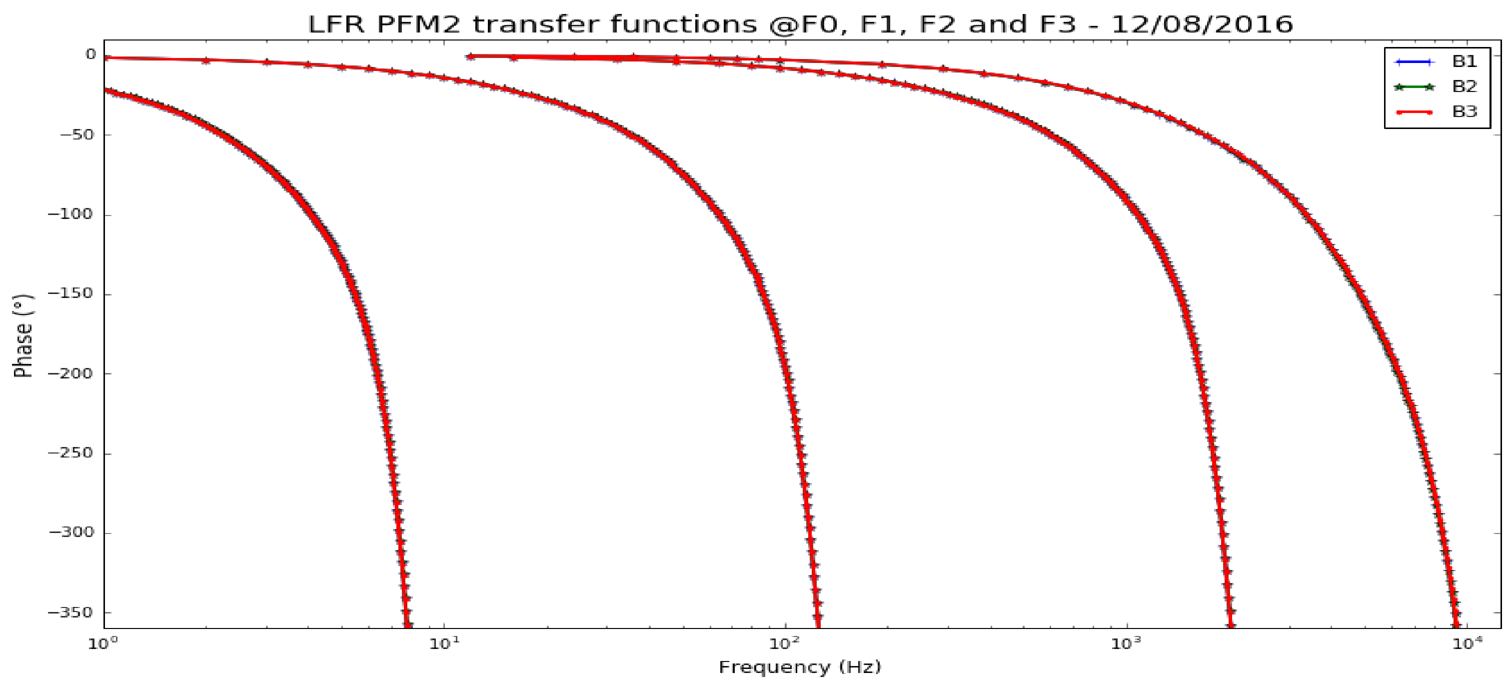


BIAS 5 analog inputs and the R-parameters

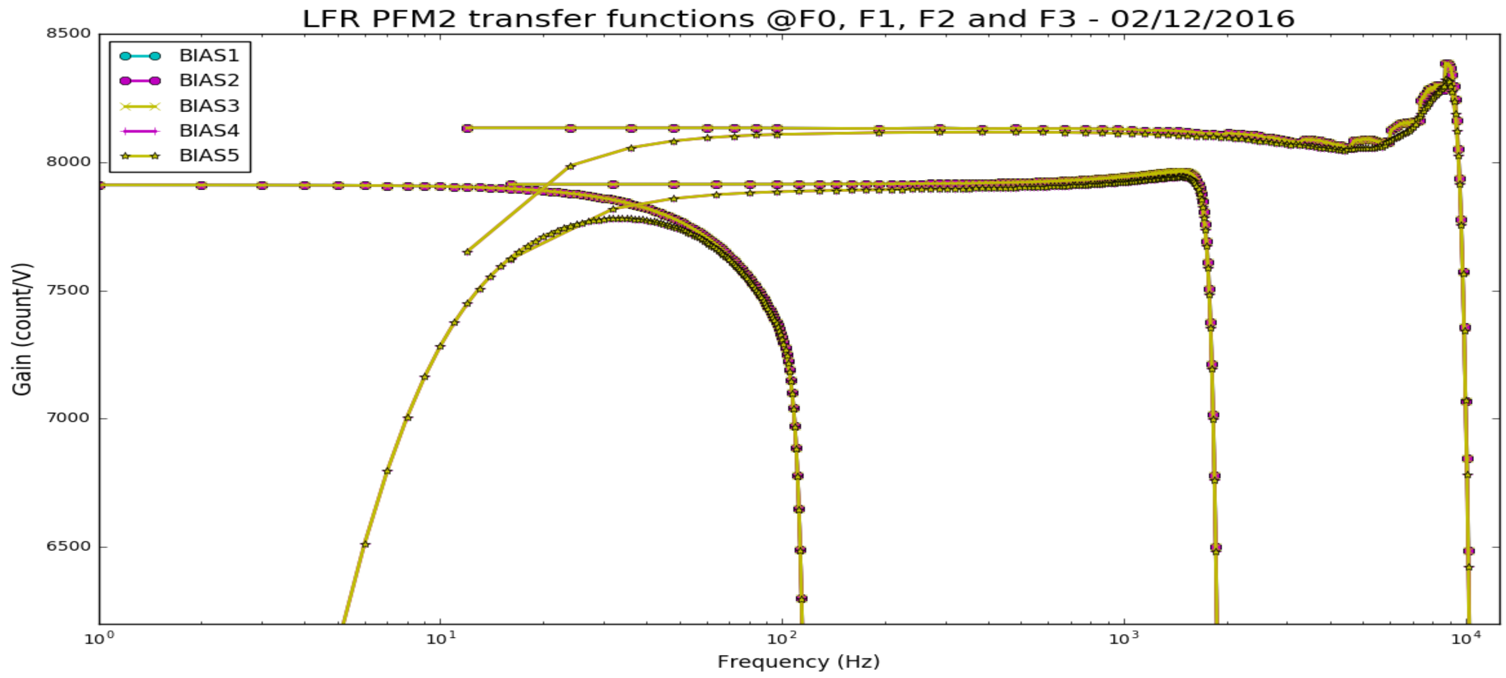


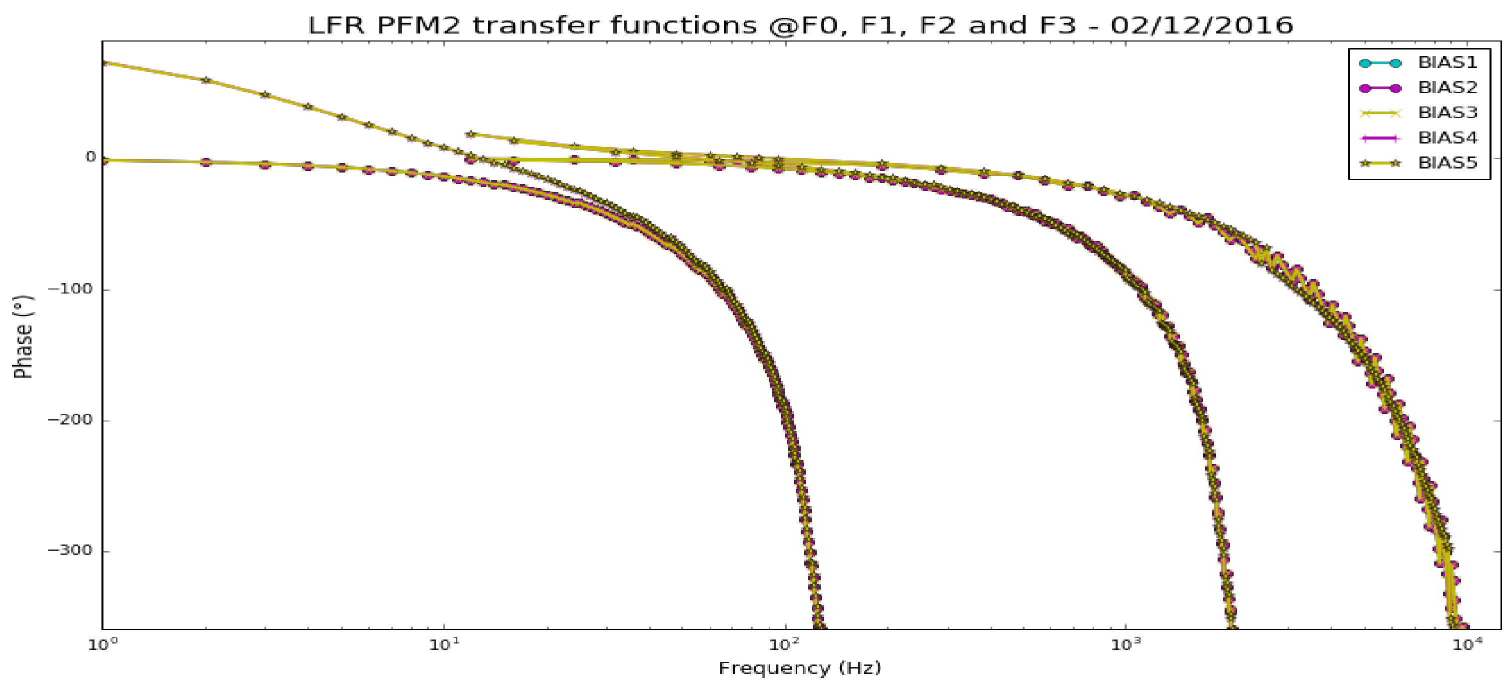
LFR SCM Transfer Fonctions



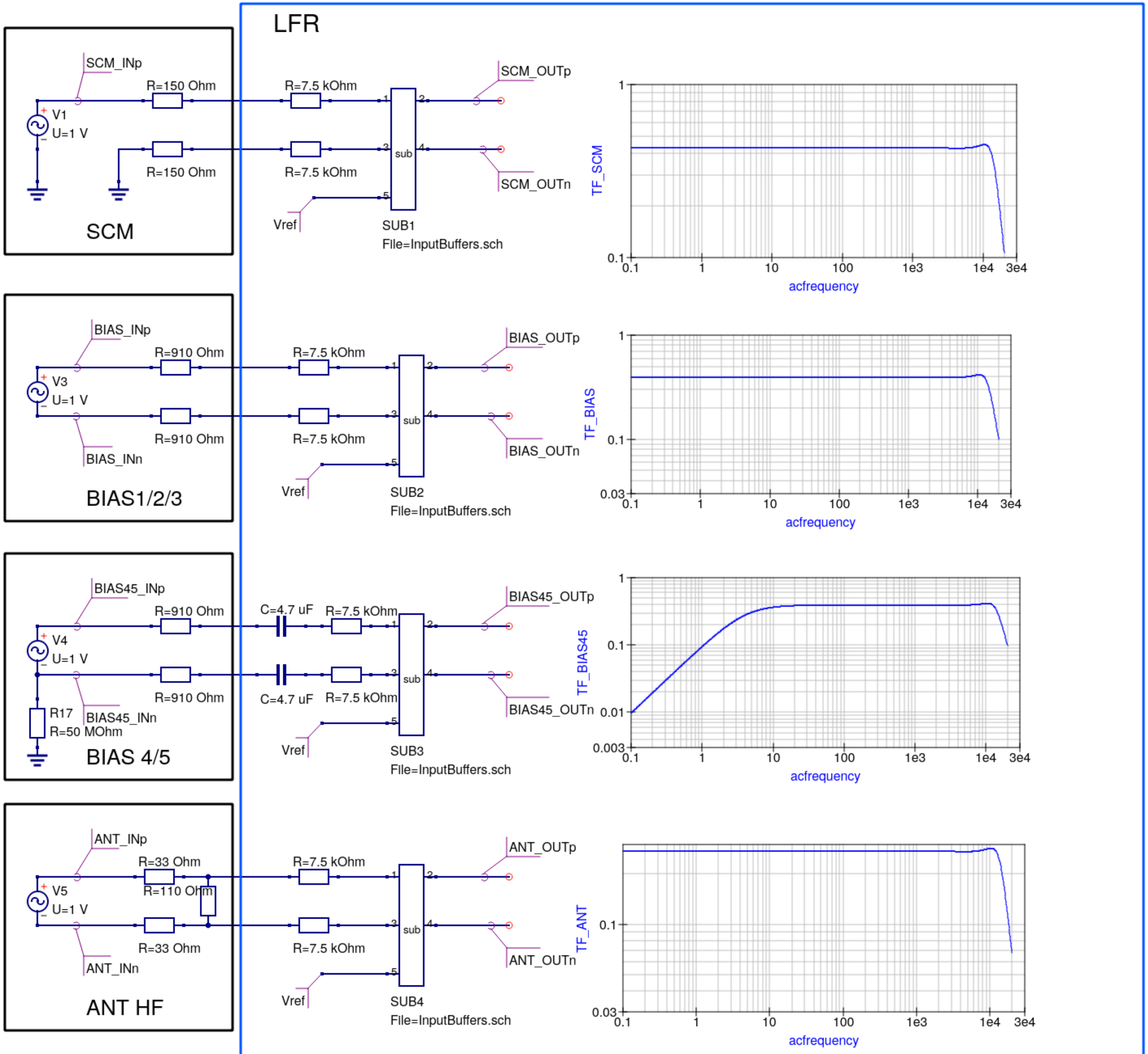


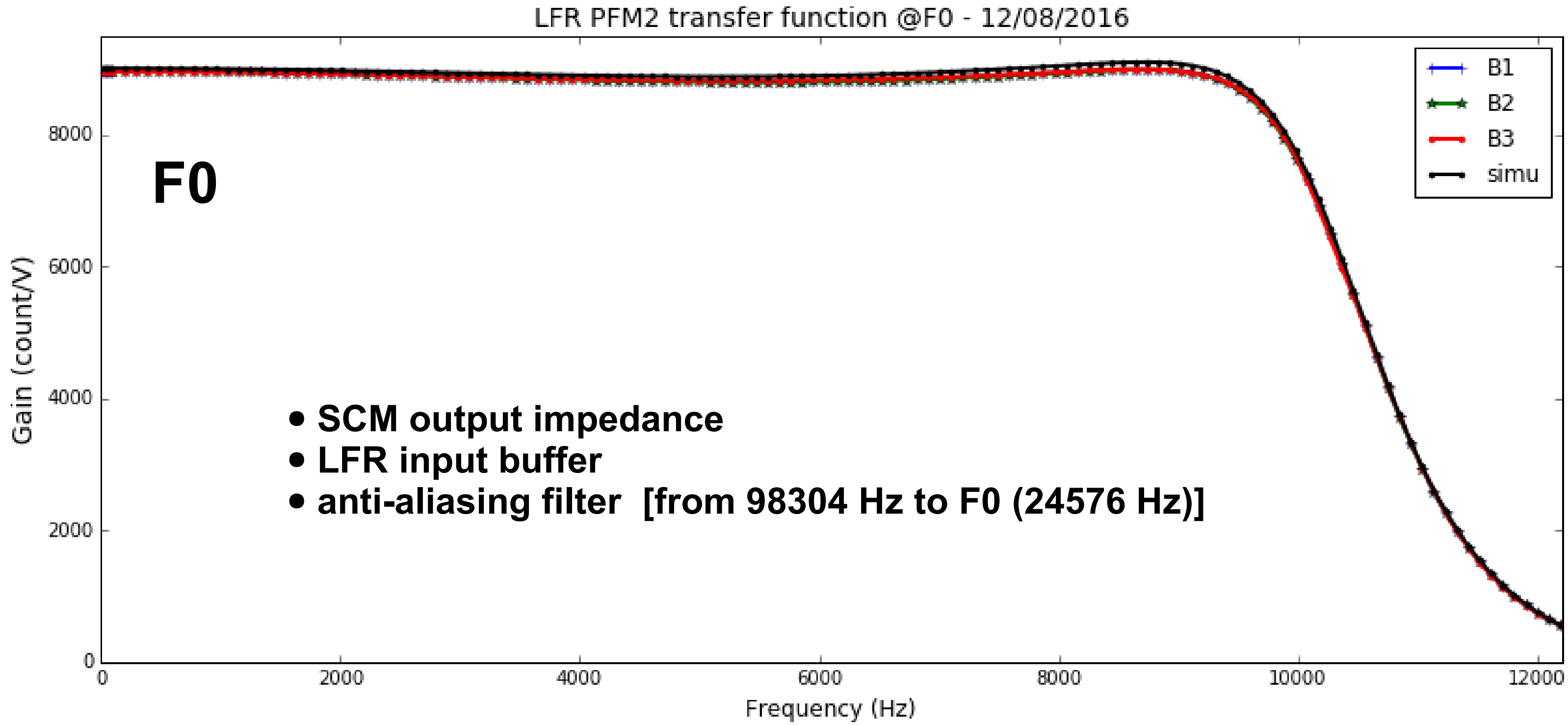
LFR BIAS Transfer Fonctions





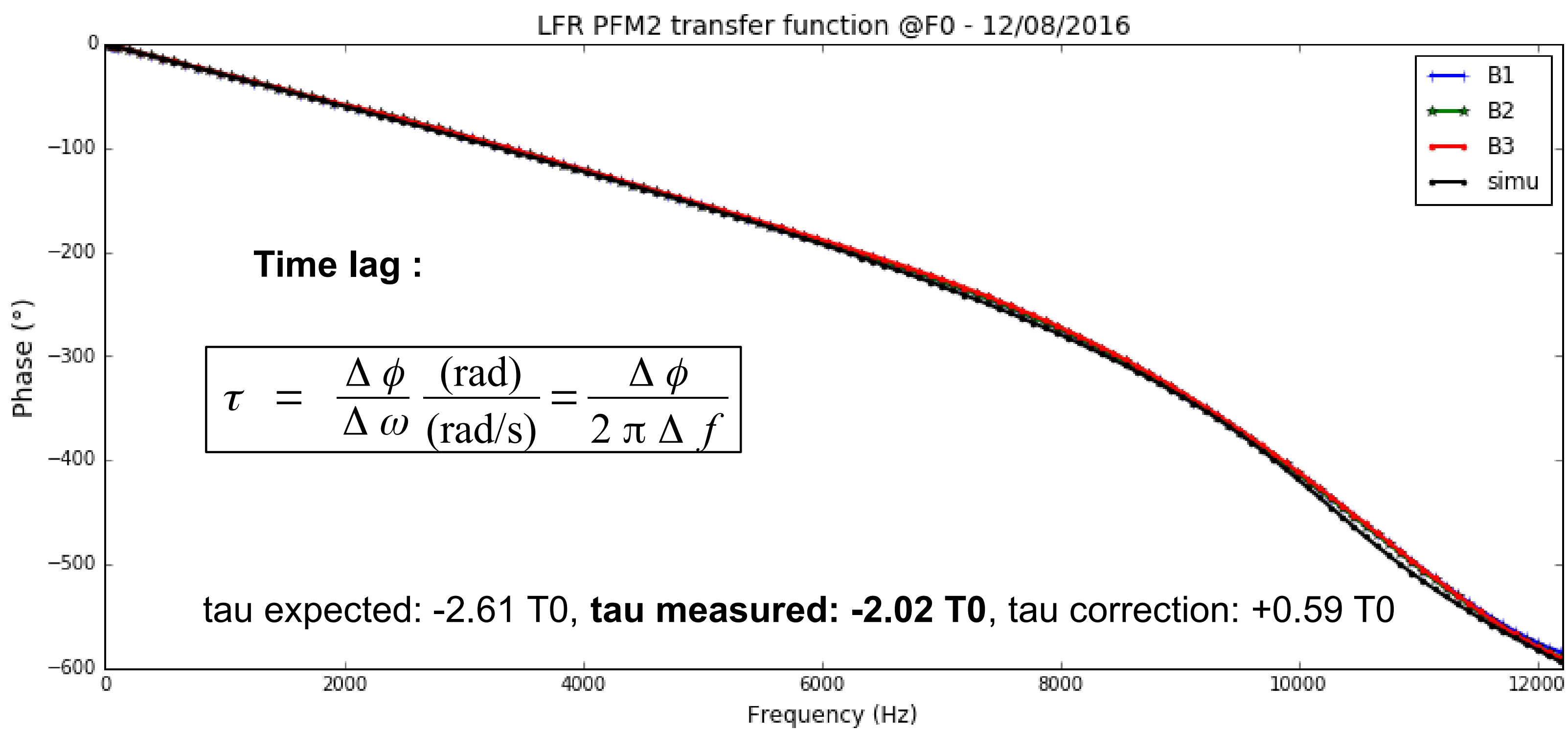
(Qucs) Simulation of the sensor output - LFR input TF





F0

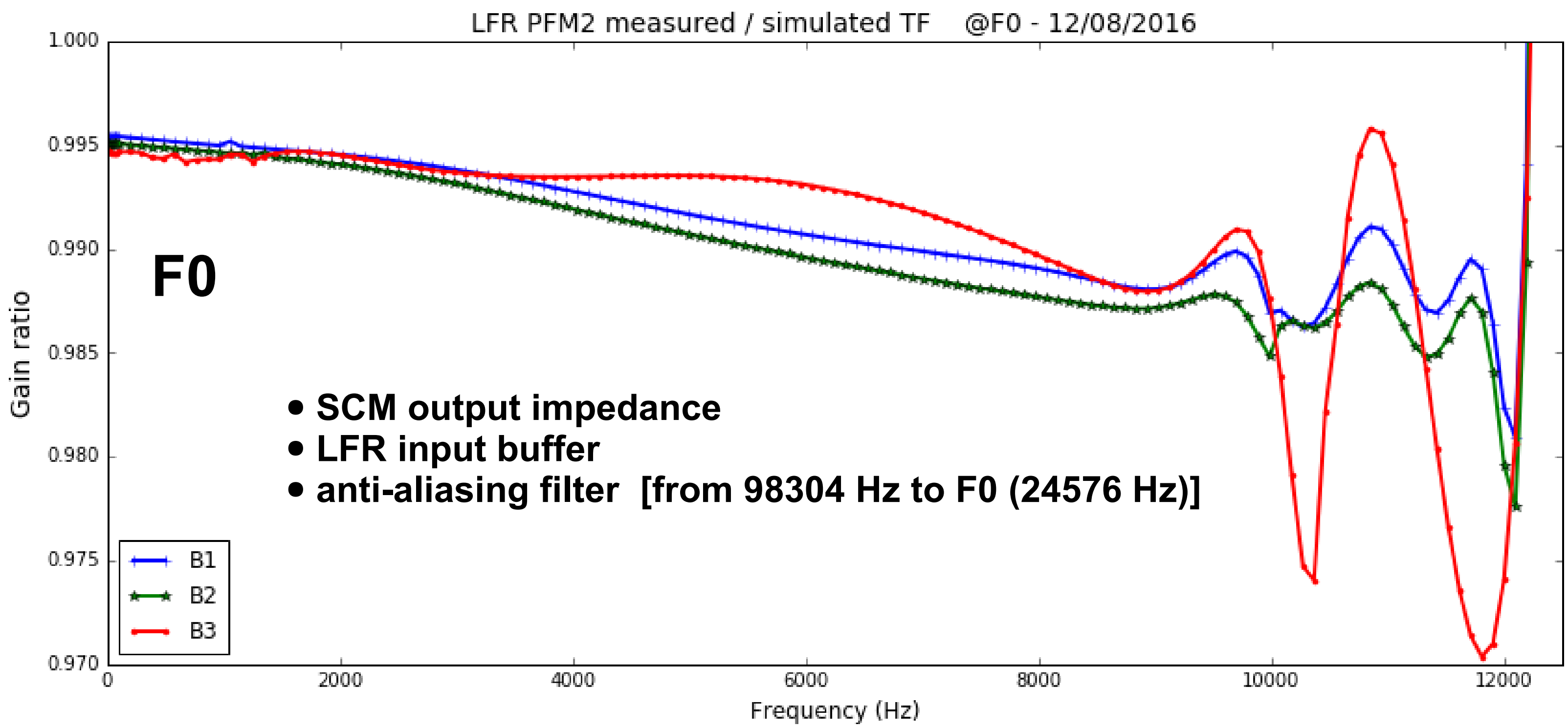
- SCM output impedance
- LFR input buffer
- anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]

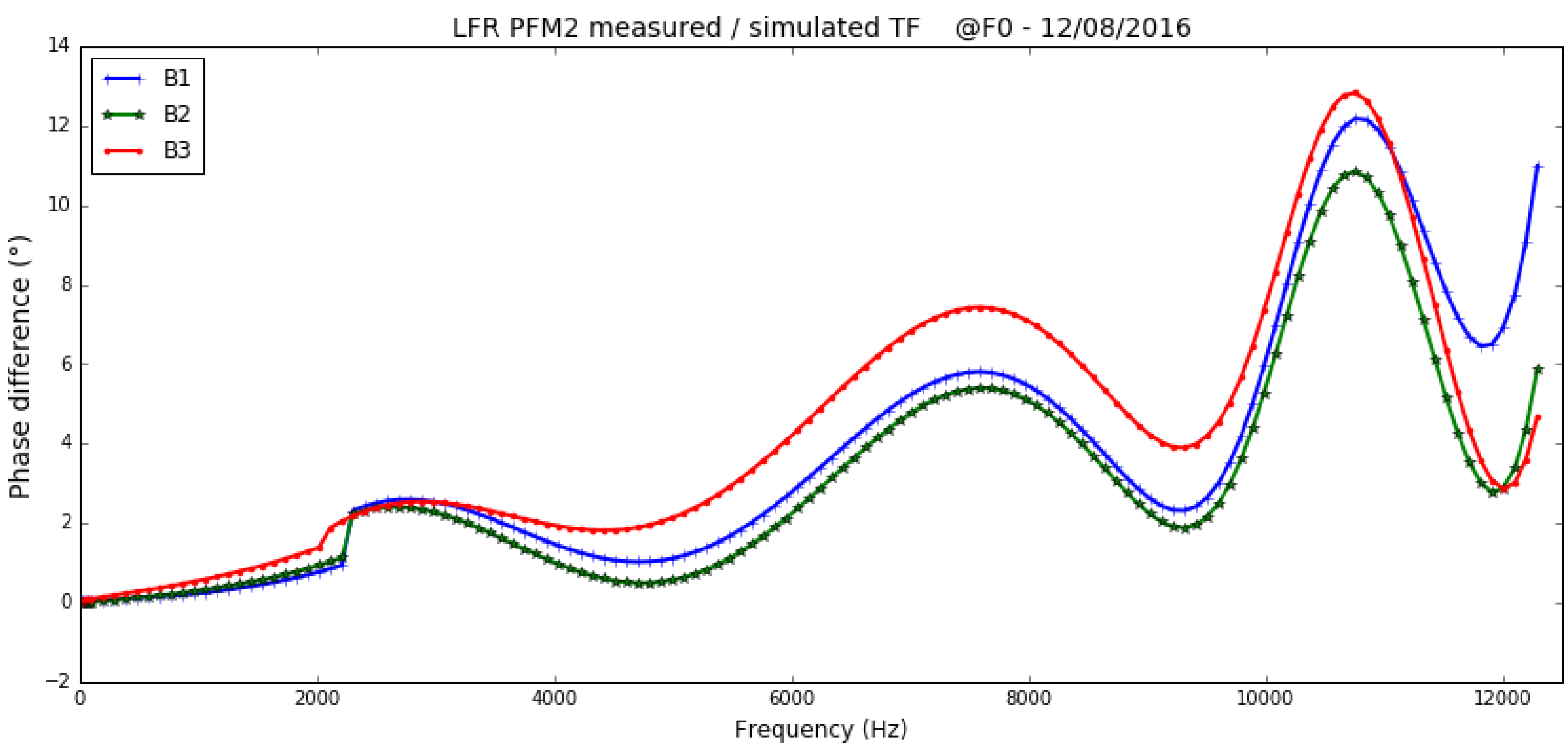


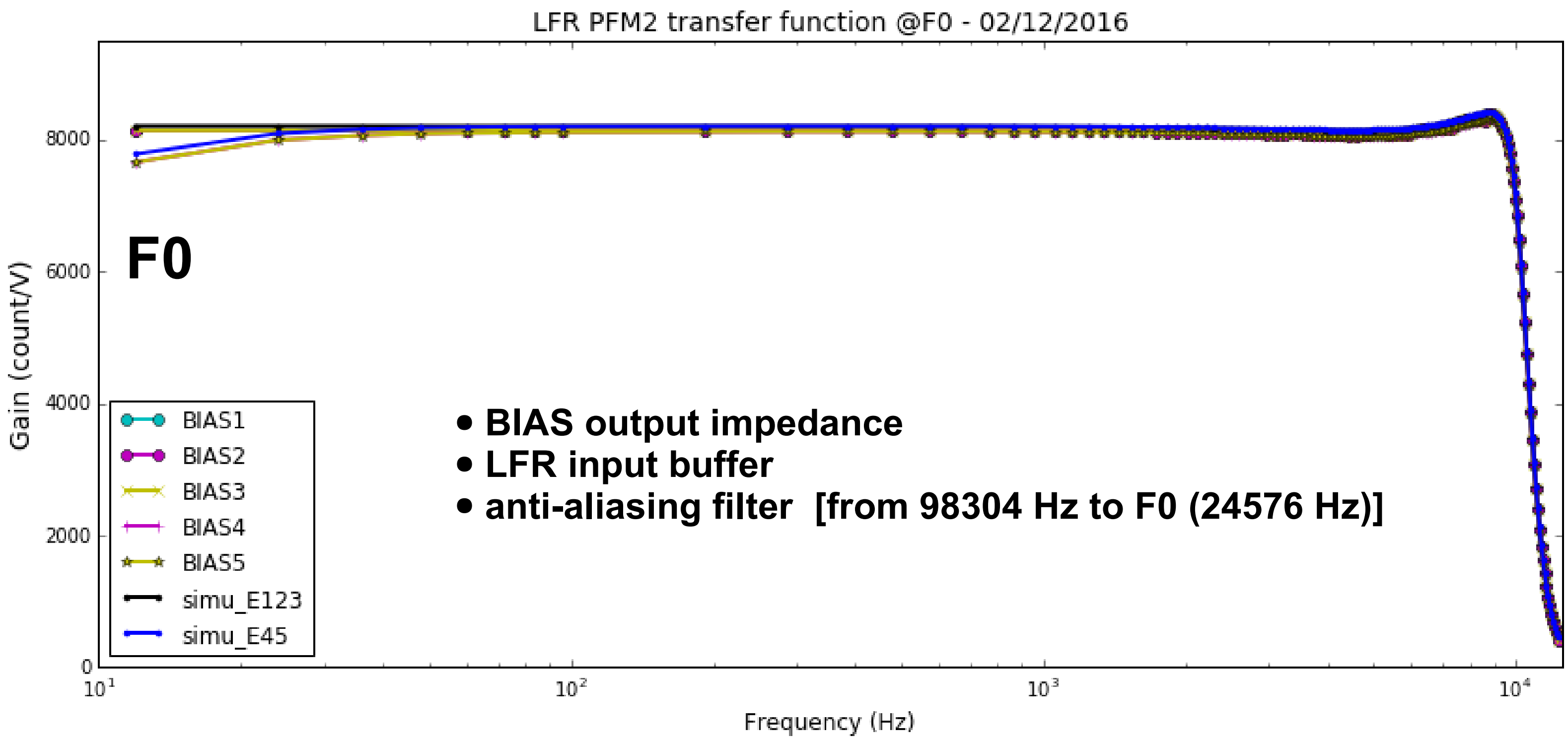
Time lag :

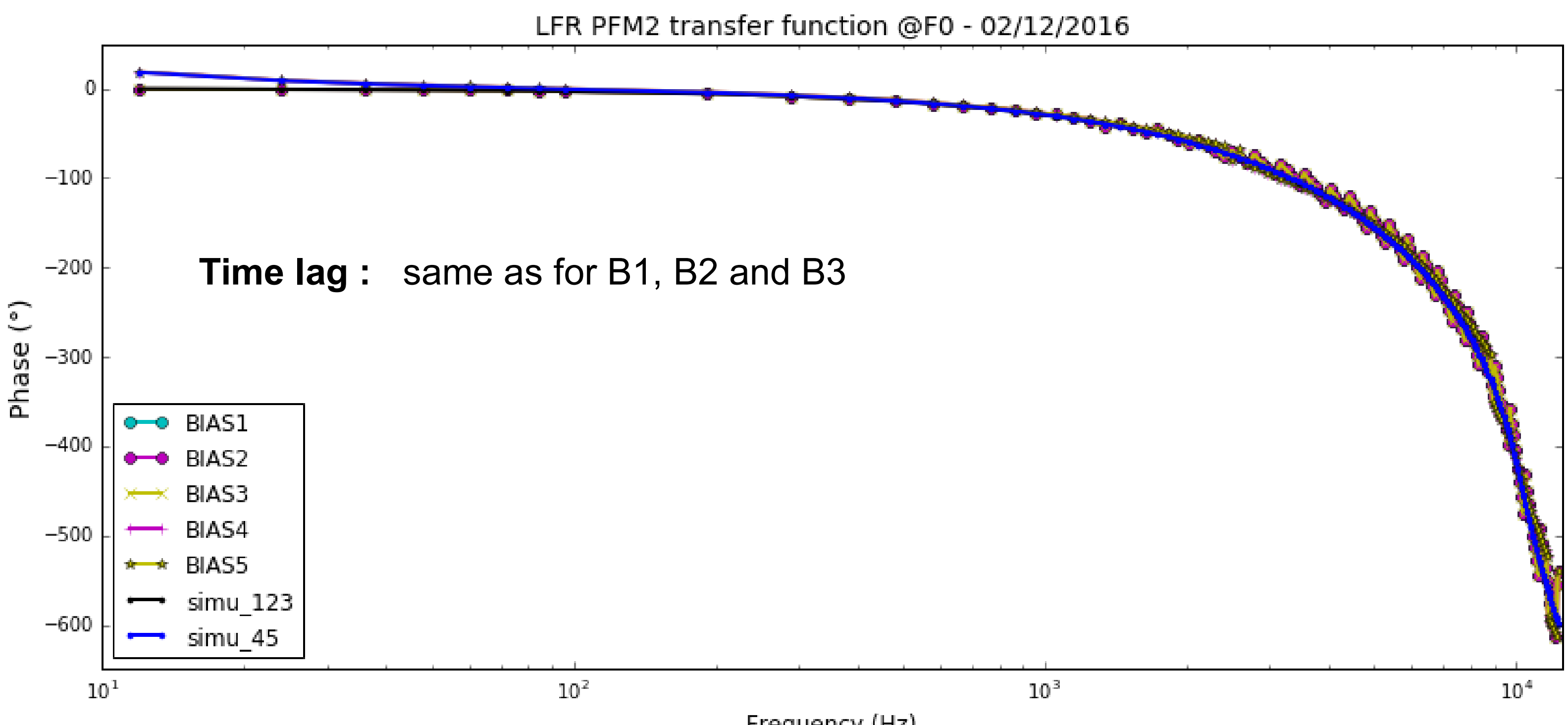
$$\boxed{\tau = \frac{\Delta\phi}{\Delta\omega}\frac{\text{(rad)}}{\text{(rad/s)}} = \frac{\Delta\phi}{2\,\pi\,\Delta f}}$$

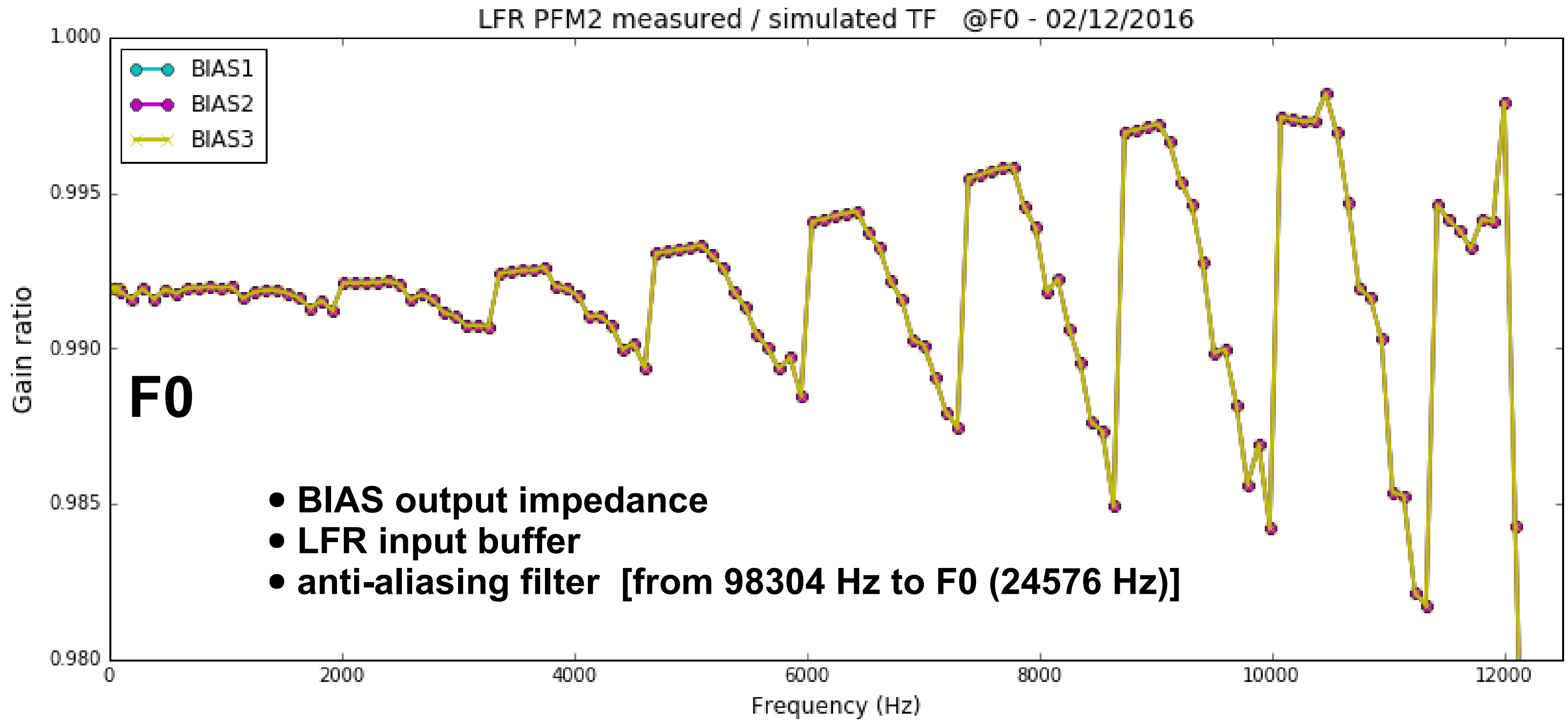
tau expected: -2.61 T0, **tau measured: -2.02 T0**, tau correction: +0.59 T0


LFR PFM2 measured / simulated TF   @F0 - 12/08/2016
F0
• SCM output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
B1
B2
B3
Gain ratio
Frequency (Hz)

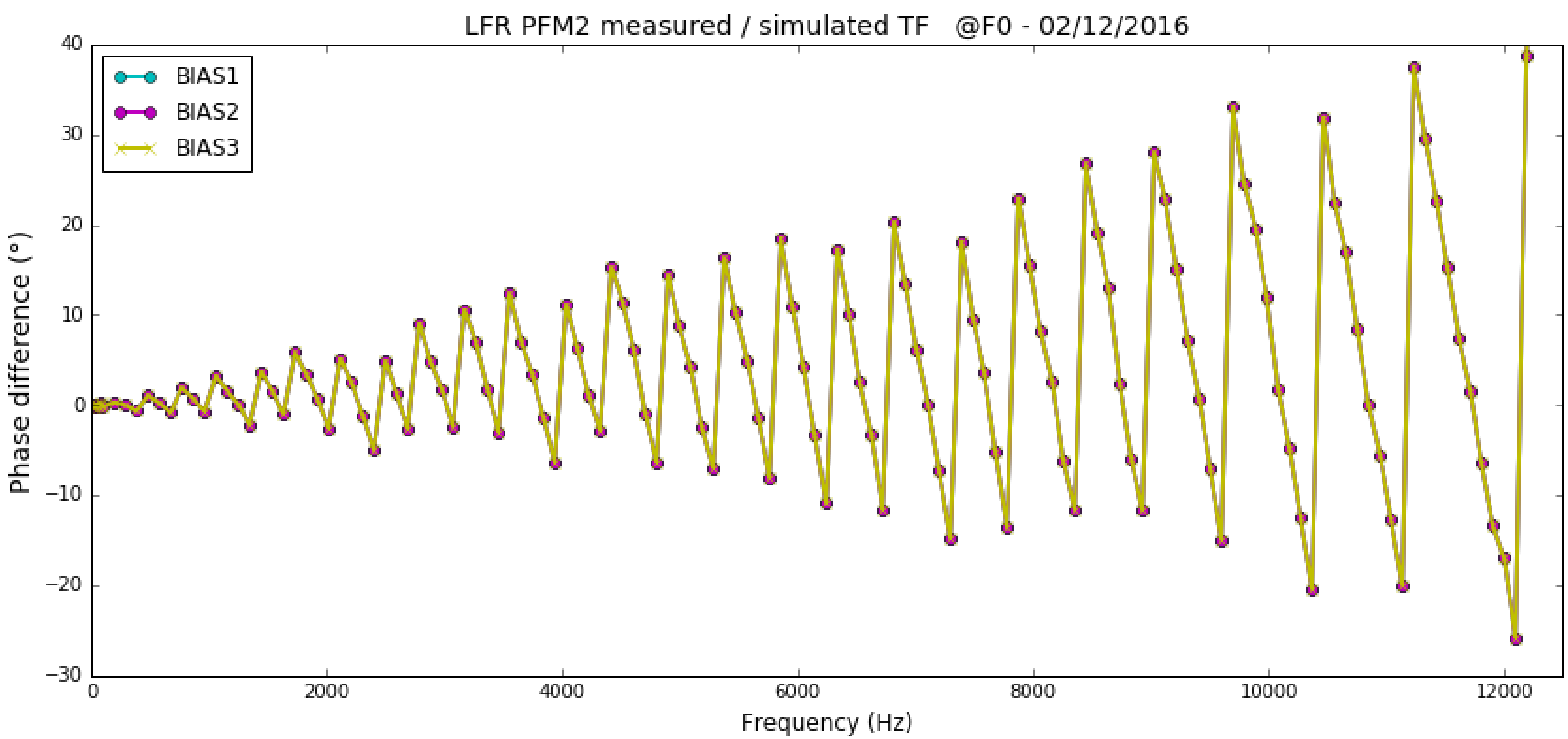

LFR PFM2 measured / simulated TF   @F0 - 12/08/2016
B1
B2
B3
Phase difference (°)
Frequency (Hz)


LFR PFM2 transfer function @F0 - 02/12/2016
F0
Gain (count/V)
8000
6000
4000
2000
0
BIAS1
BIAS2
BIAS3
BIAS4
BIAS5
simu_E123
simu_E45
• BIAS output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
Frequency (Hz)

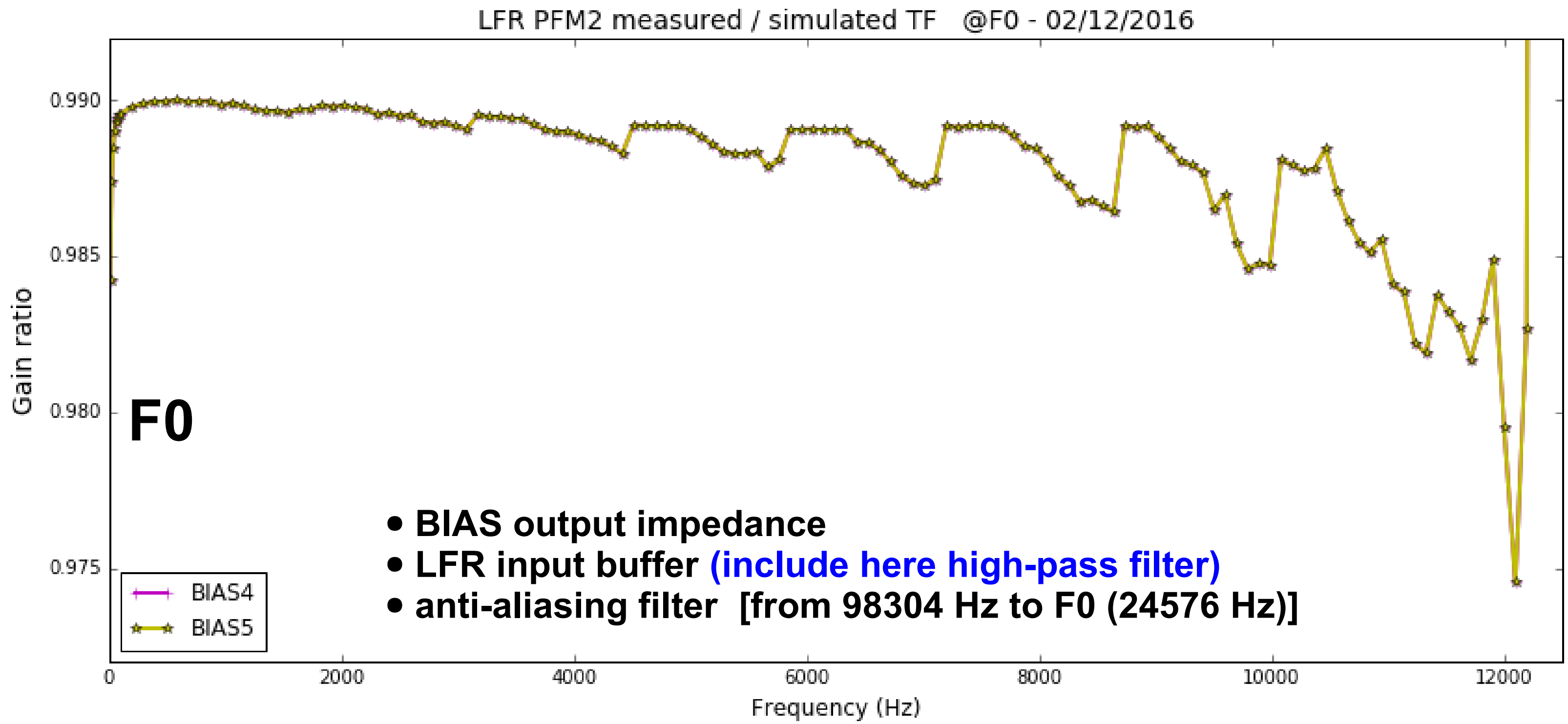

LFR PFM2 transfer function @F0 - 02/12/2016
Phase (°)
0
−100
−200
−300
−400
−500
−600
Time lag : same as for B1, B2 and B3
BIAS1
BIAS2
BIAS3
BIAS4
BIAS5
simu_123
simu_45
Frequency (Hz)



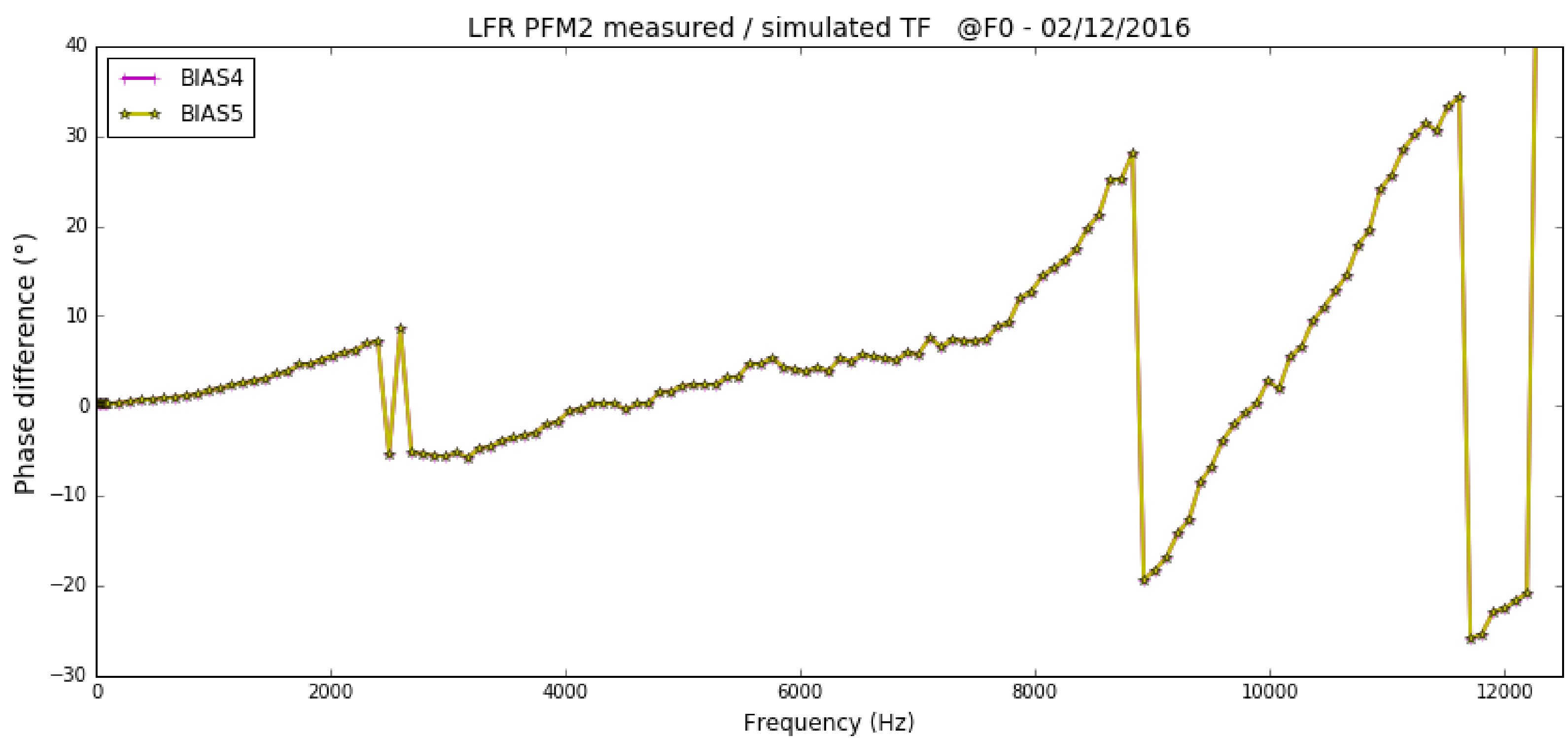
LFR PFM2 measured / simulated TF @F0 - 02/12/2016
BIAS1
BIAS2
BIAS3
Gain ratio
Frequency (Hz)
F0
• BIAS output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]



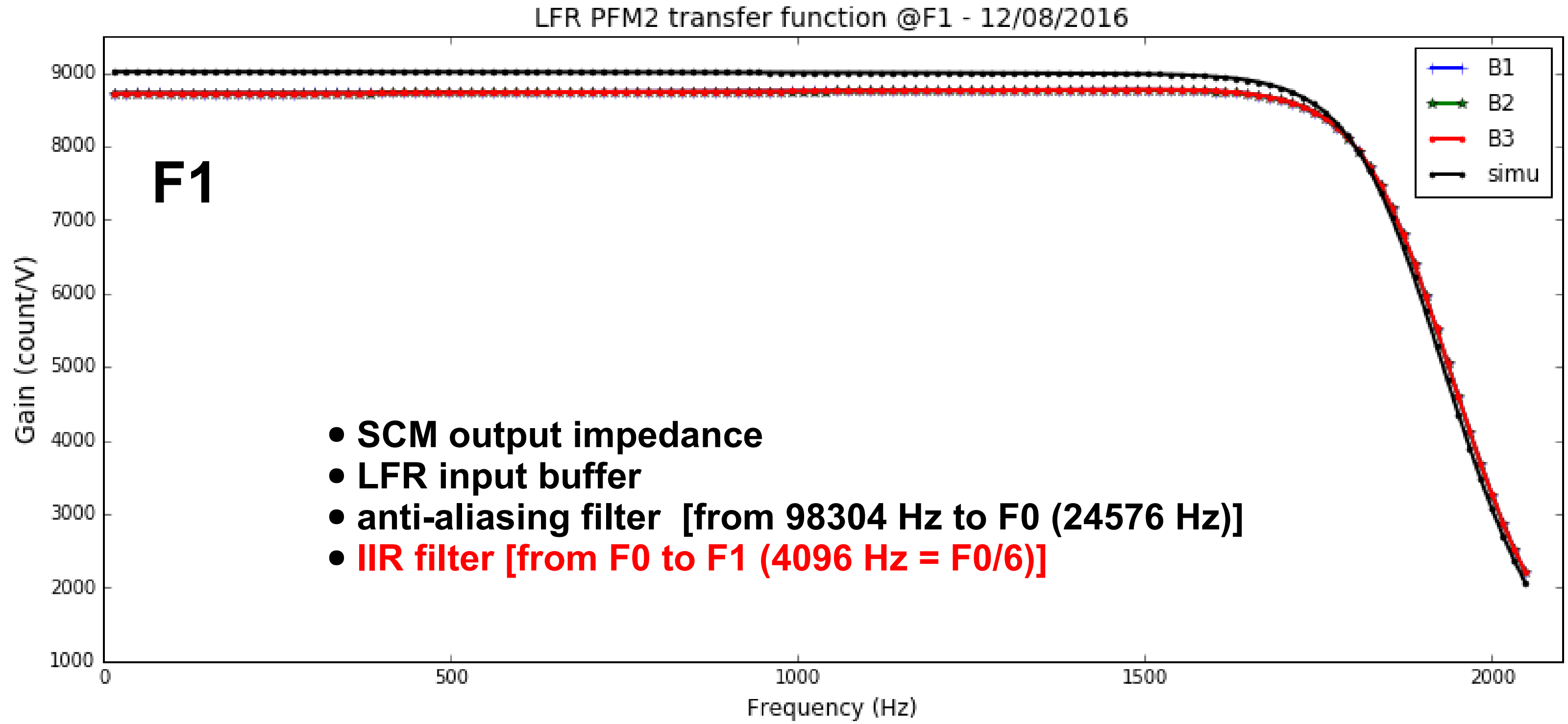
LFR PFM2 measured / simulated TF @F0 - 02/12/2016
BIAS1
BIAS2
BIAS3
Phase difference (°)
Frequency (Hz)

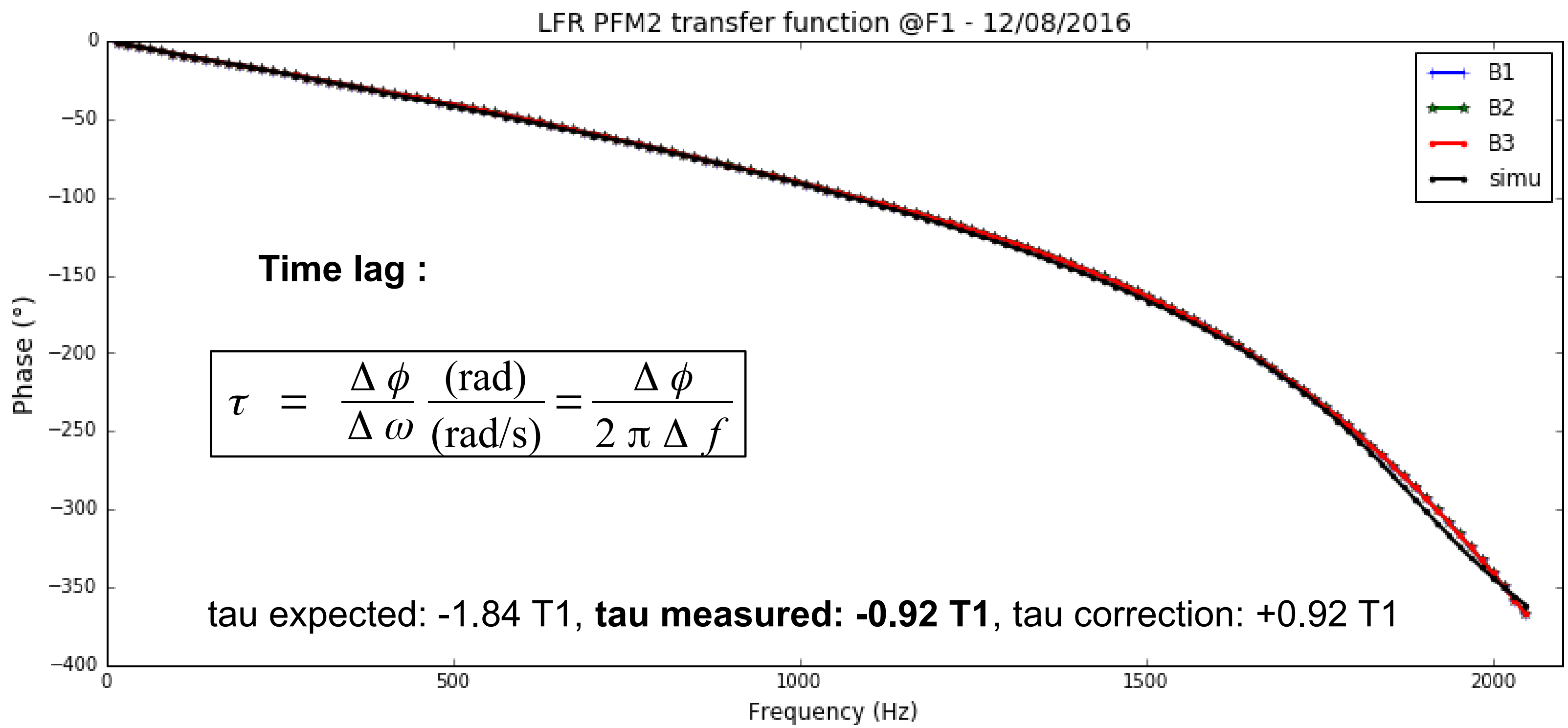


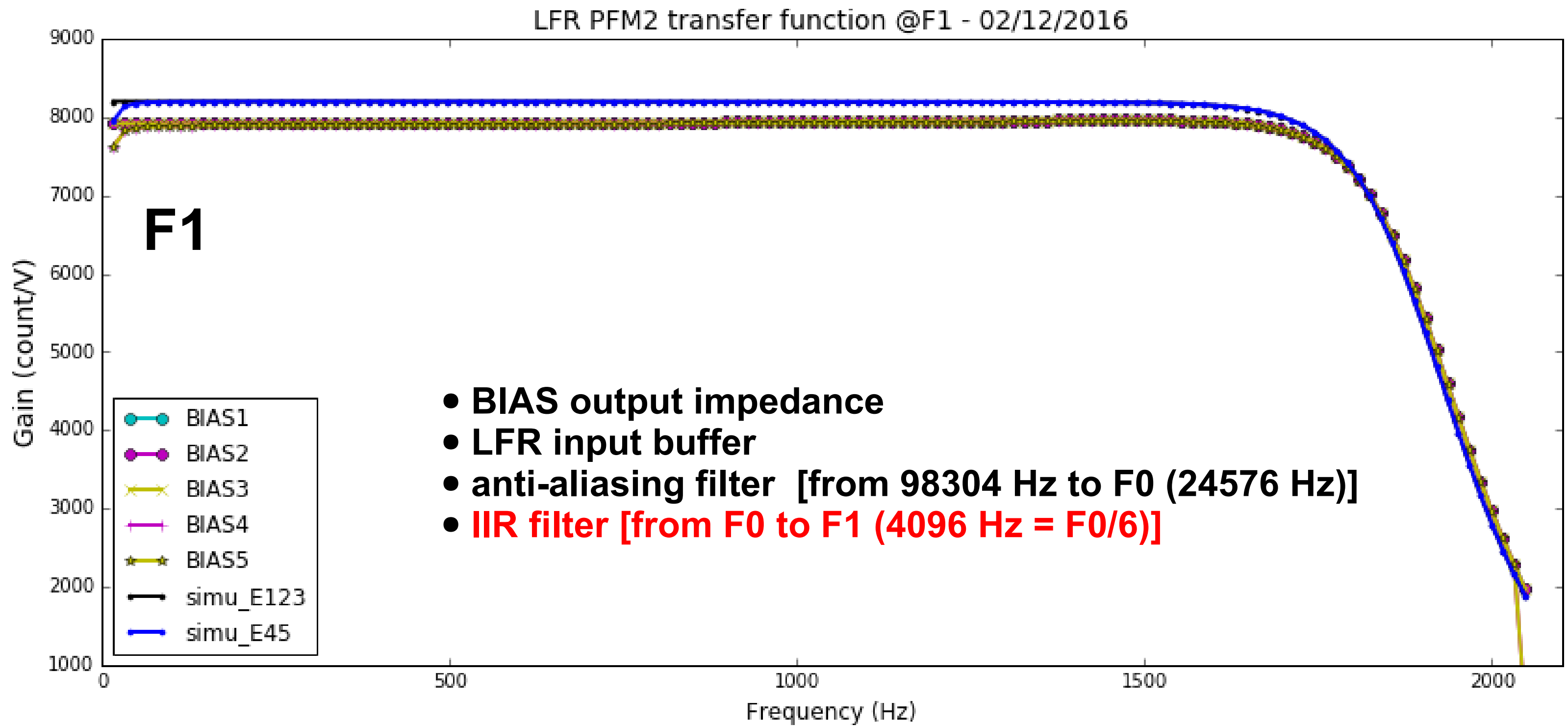
LFR PFM2 measured / simulated TF @F0 - 02/12/2016
Gain ratio
0.990
0.985
0.980
0.975
F0
• BIAS output impedance
• LFR input buffer (include here high-pass filter)
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
BIAS4
BIAS5
0
2000
4000
6000
8000
10000
12000
Frequency (Hz)

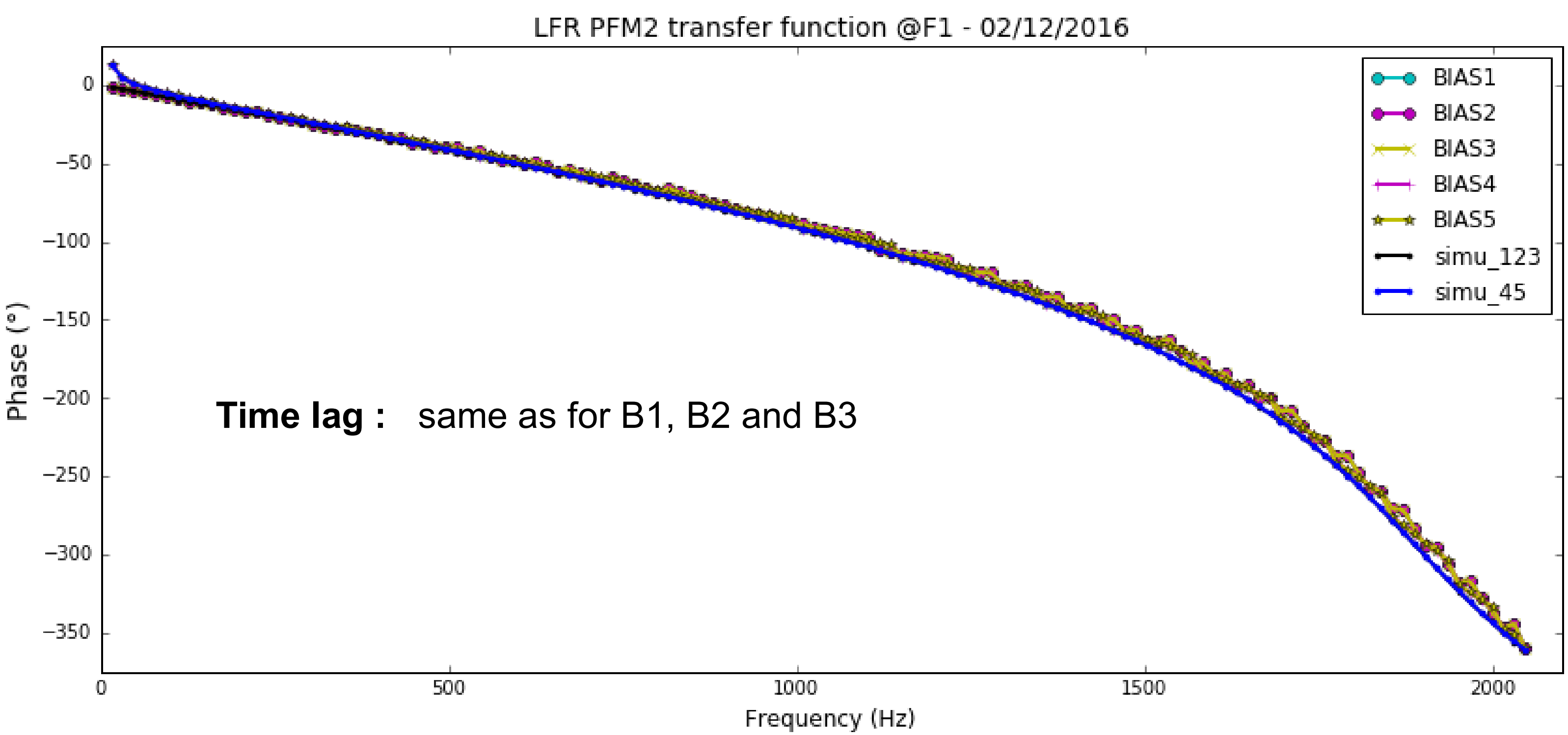


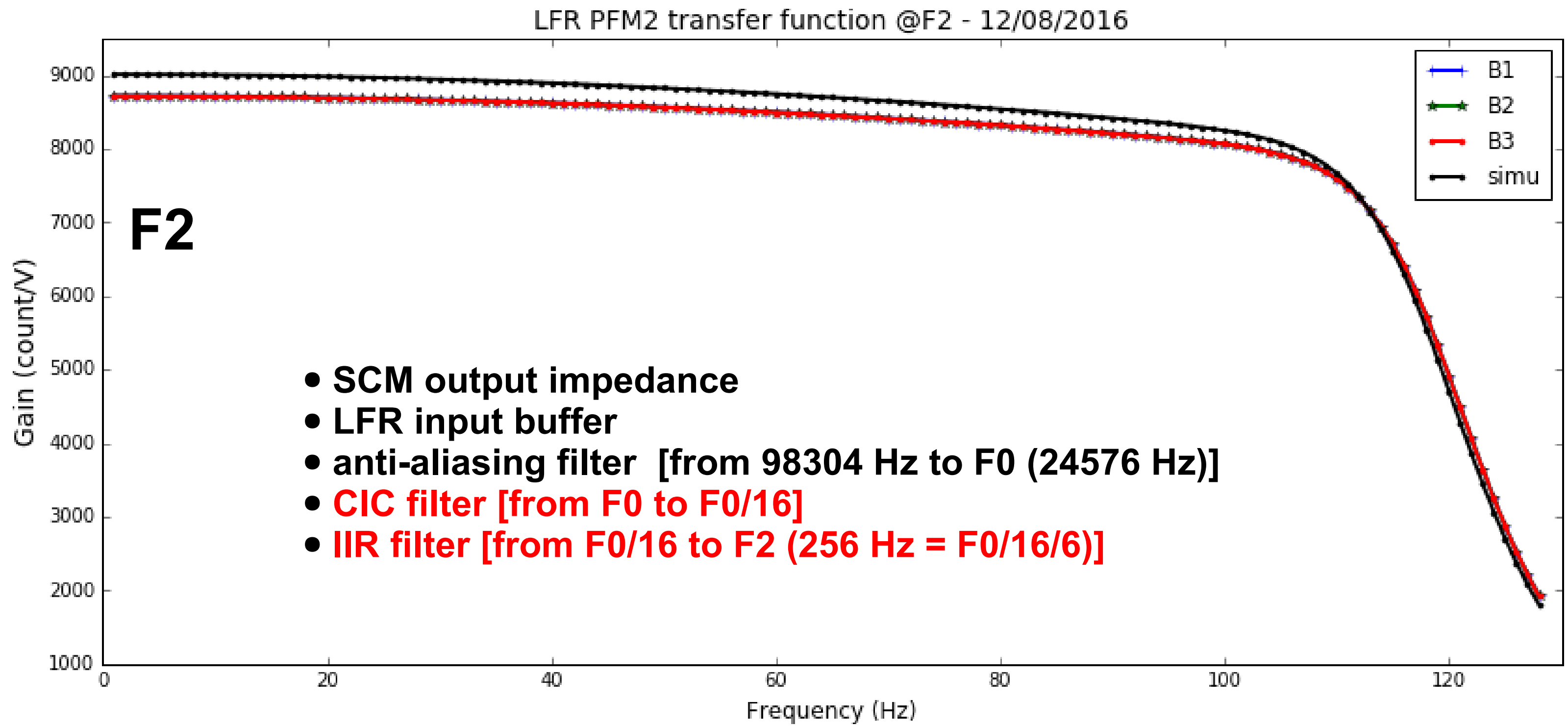
LFR PFM2 measured / simulated TF @F0 - 02/12/2016
Phase difference (°)
40
30
20
10
0
−10
−20
−30
BIAS4
BIAS5
0
2000
4000
6000
8000
10000
12000
Frequency (Hz)

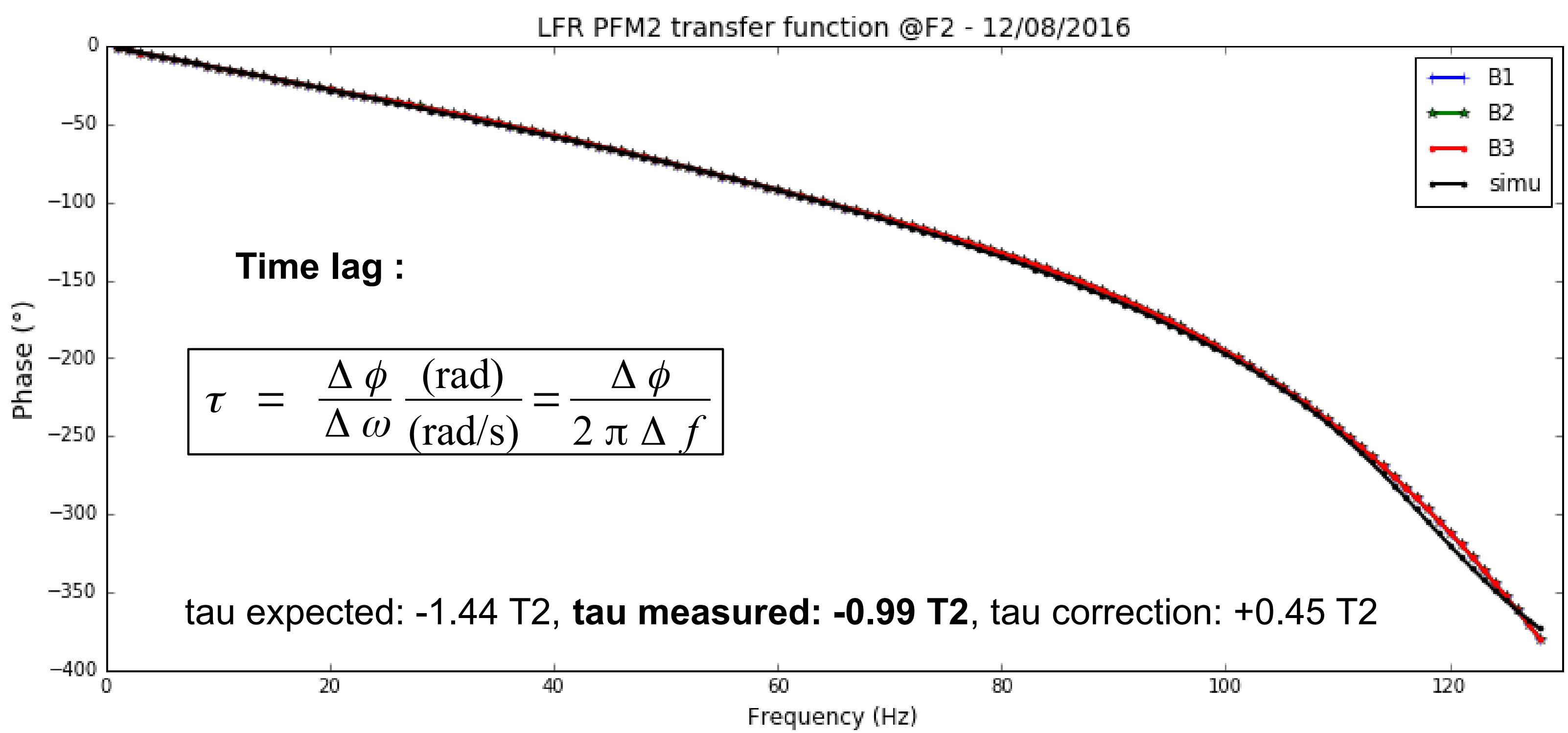

LFR PFM2 transfer function @F1 - 12/08/2016
F1
• SCM output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
• IIR filter [from F0 to F1 (4096 Hz = F0/6)]
B1
B2
B3
simu
Gain (count/V)
Frequency (Hz)

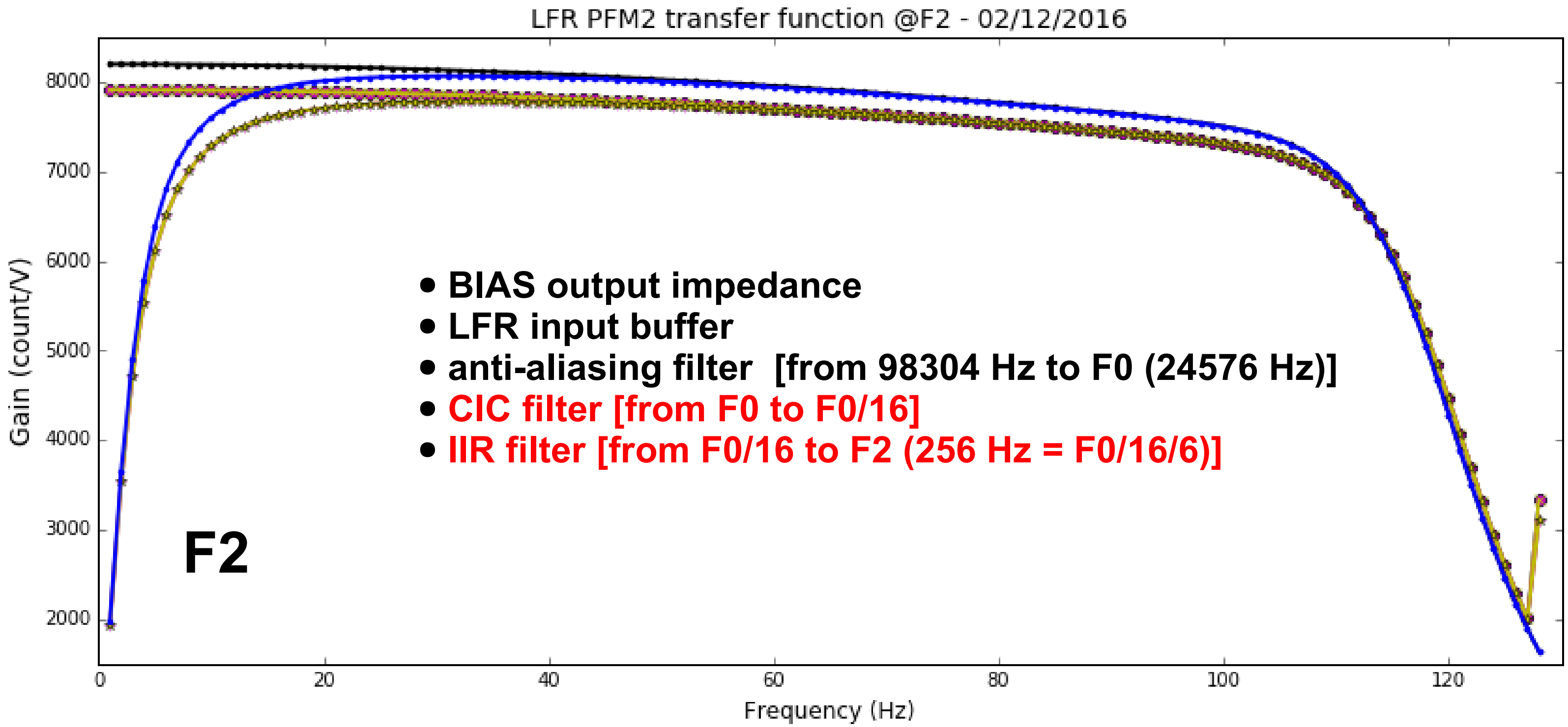

LFR PFM2 transfer function @F1 - 12/08/2016
Time lag :
$\tau = \frac{\Delta \phi}{\Delta \omega} \frac{(\mathrm{rad})}{(\mathrm{rad/s})} = \frac{\Delta \phi}{2 \pi \Delta f}$
tau expected: -1.84 T1, **tau measured: -0.92 T1**, tau correction: +0.92 T1
B1
B2
B3
simu
Phase (°)
Frequency (Hz)

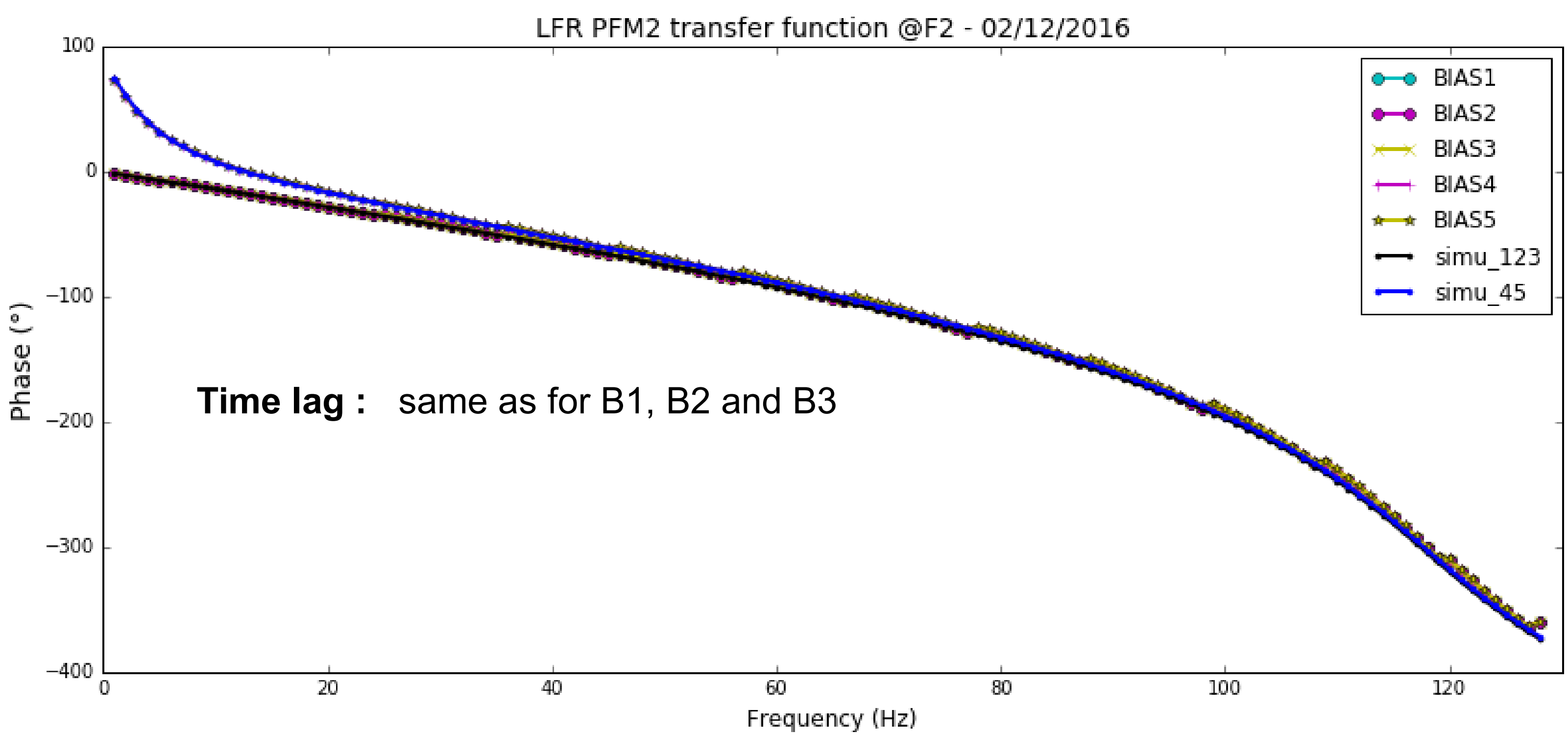

LFR PFM2 transfer function @F1 - 02/12/2016
F1
• BIAS output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
• IIR filter [from F0 to F1 (4096 Hz = F0/6)]
BIAS1
BIAS2
BIAS3
BIAS4
BIAS5
simu_E123
simu_E45
Gain (count/V)
Frequency (Hz)

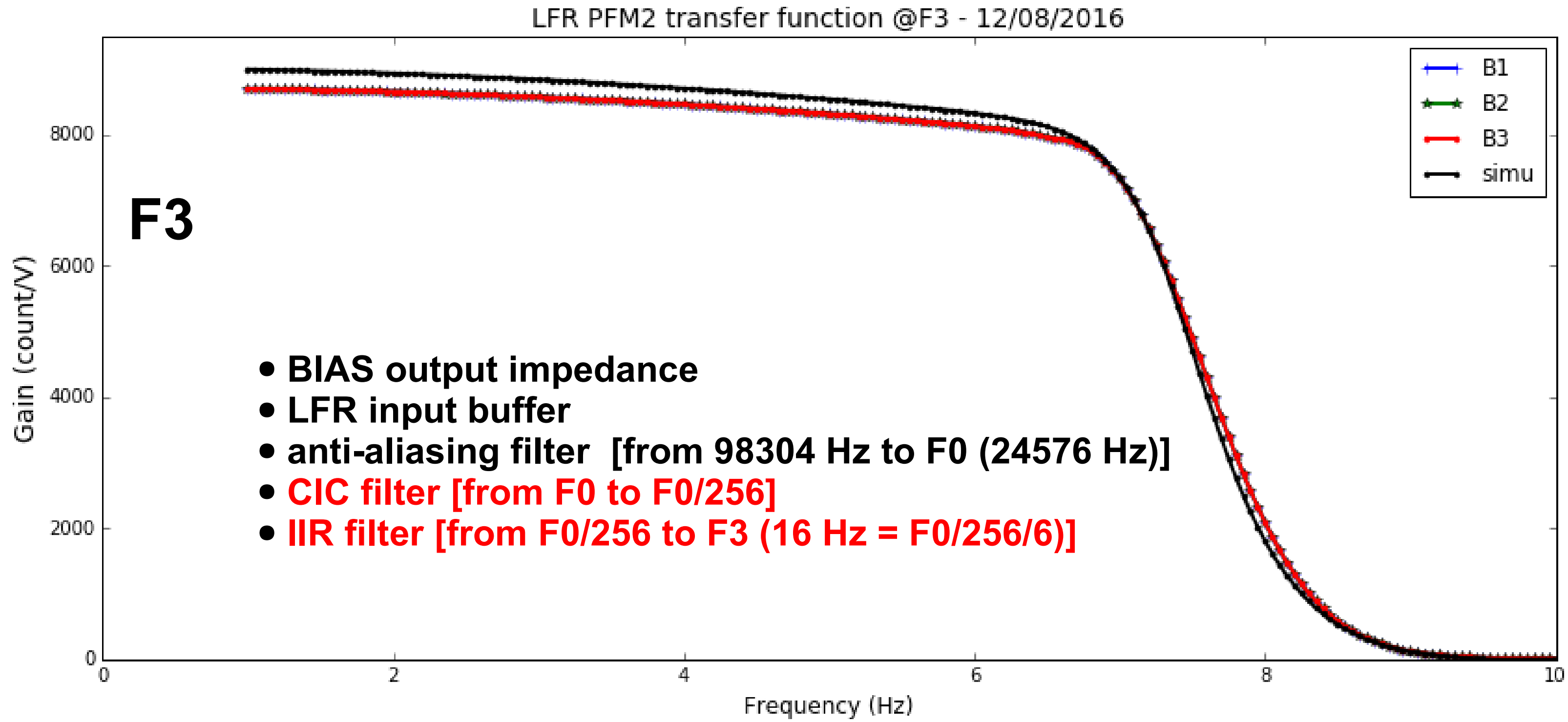

LFR PFM2 transfer function @F1 - 02/12/2016
Time lag : same as for B1, B2 and B3
BIAS1
BIAS2
BIAS3
BIAS4
BIAS5
simu_123
simu_45
Phase (°)
Frequency (Hz)


LFR PFM2 transfer function @F2 - 12/08/2016
F2
• SCM output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
• CIC filter [from F0 to F0/16]
• IIR filter [from F0/16 to F2 (256 Hz = F0/16/6)]
B1
B2
B3
simu
Gain (count/V)
Frequency (Hz)


LFR PFM2 transfer function @F2 - 12/08/2016
Time lag :
$\tau = \frac{\Delta\phi}{\Delta\omega}\frac{(\mathrm{rad})}{(\mathrm{rad/s})} = \frac{\Delta\phi}{2\pi\Delta f}$
tau expected: -1.44 T2, **tau measured: -0.99 T2**, tau correction: +0.45 T2
B1
B2
B3
simu
Phase (°)
Frequency (Hz)

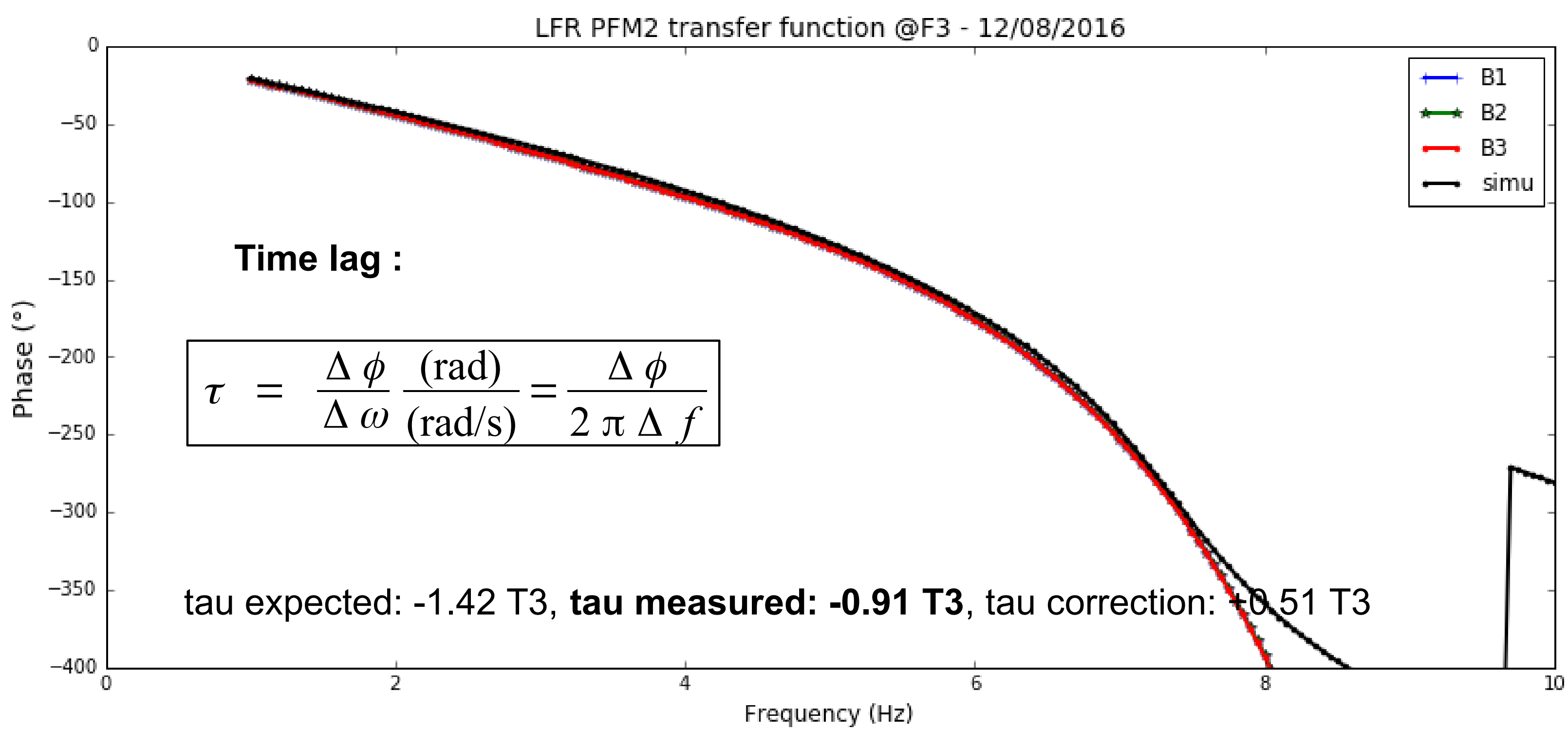

LFR PFM2 transfer function @F2 - 02/12/2016
Gain (count/V)
Frequency (Hz)
• BIAS output impedance
• LFR input buffer
• anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]
• CIC filter [from F0 to F0/16]
• IIR filter [from F0/16 to F2 (256 Hz = F0/16/6)]
F2


LFR PFM2 transfer function @F2 - 02/12/2016
Phase (°)
Frequency (Hz)
BIAS1
BIAS2
BIAS3
BIAS4
BIAS5
simu_123
simu_45
Time lag : same as for B1, B2 and B3



F3

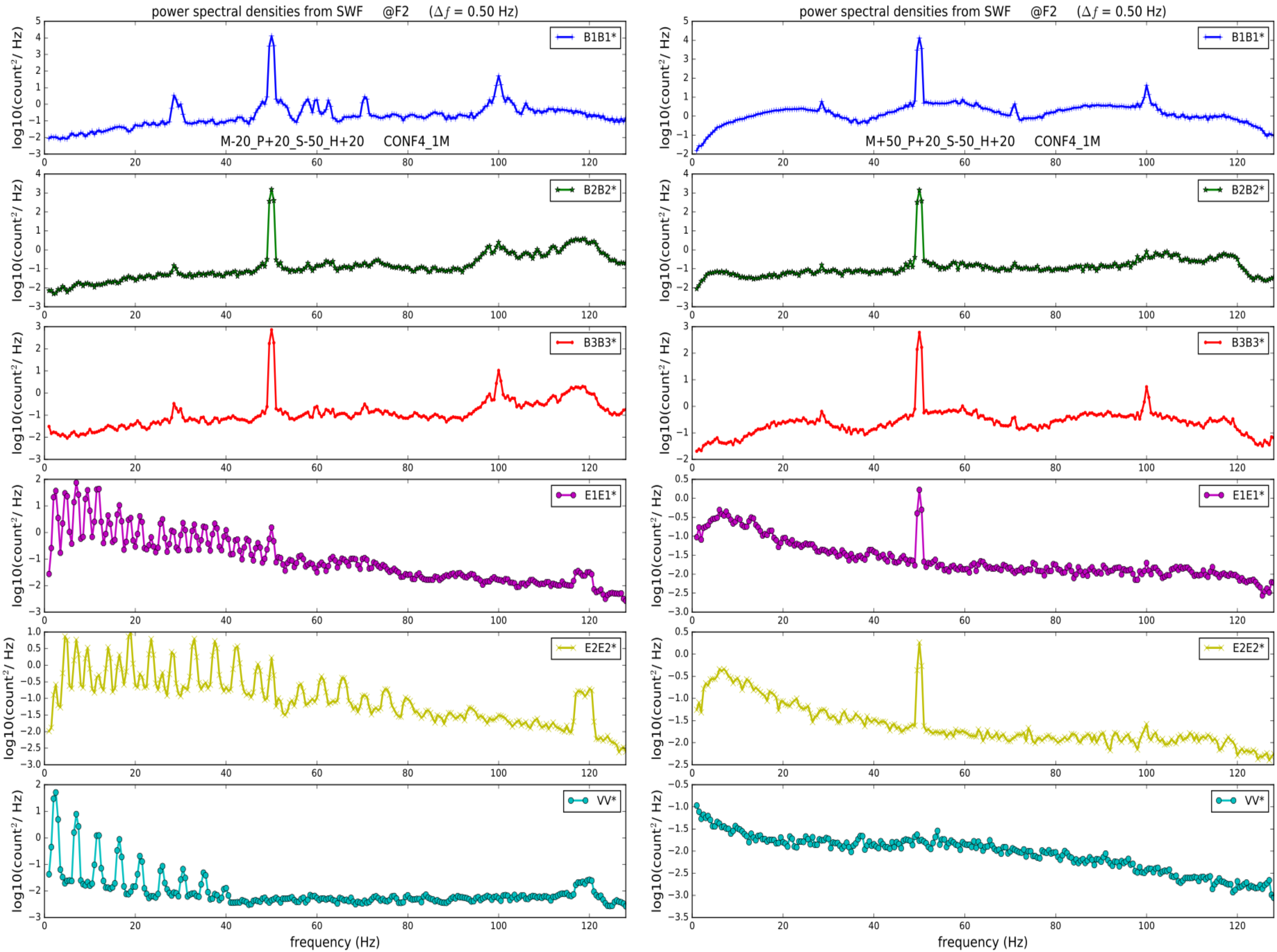
- **BIAS output impedance**
- **LFR input buffer**
- **anti-aliasing filter [from 98304 Hz to F0 (24576 Hz)]**
- **CIC filter [from F0 to F0/256]**
- **IIR filter [from F0/256 to F3 (16 Hz = F0/256/6)]**



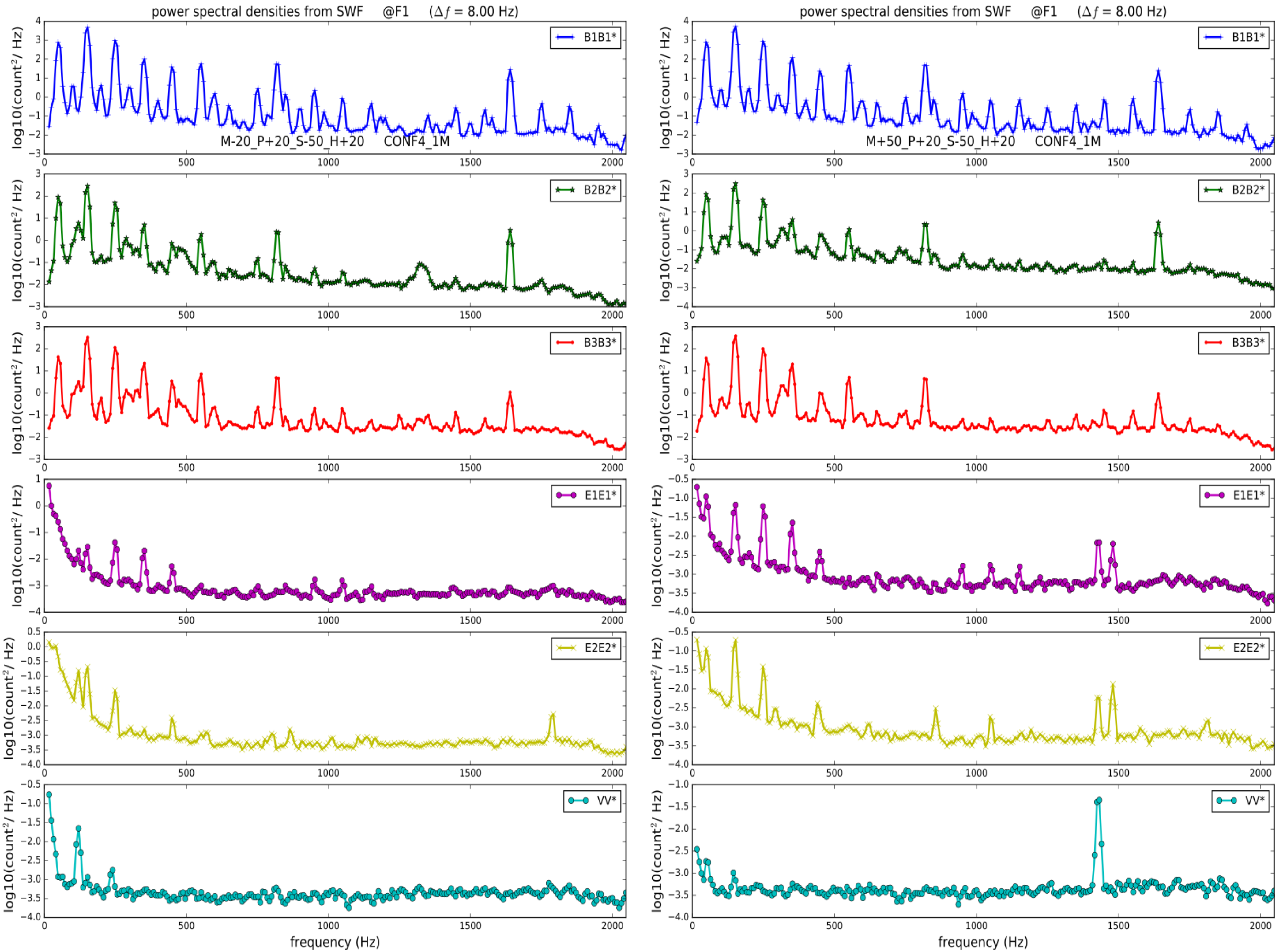
Time lag :

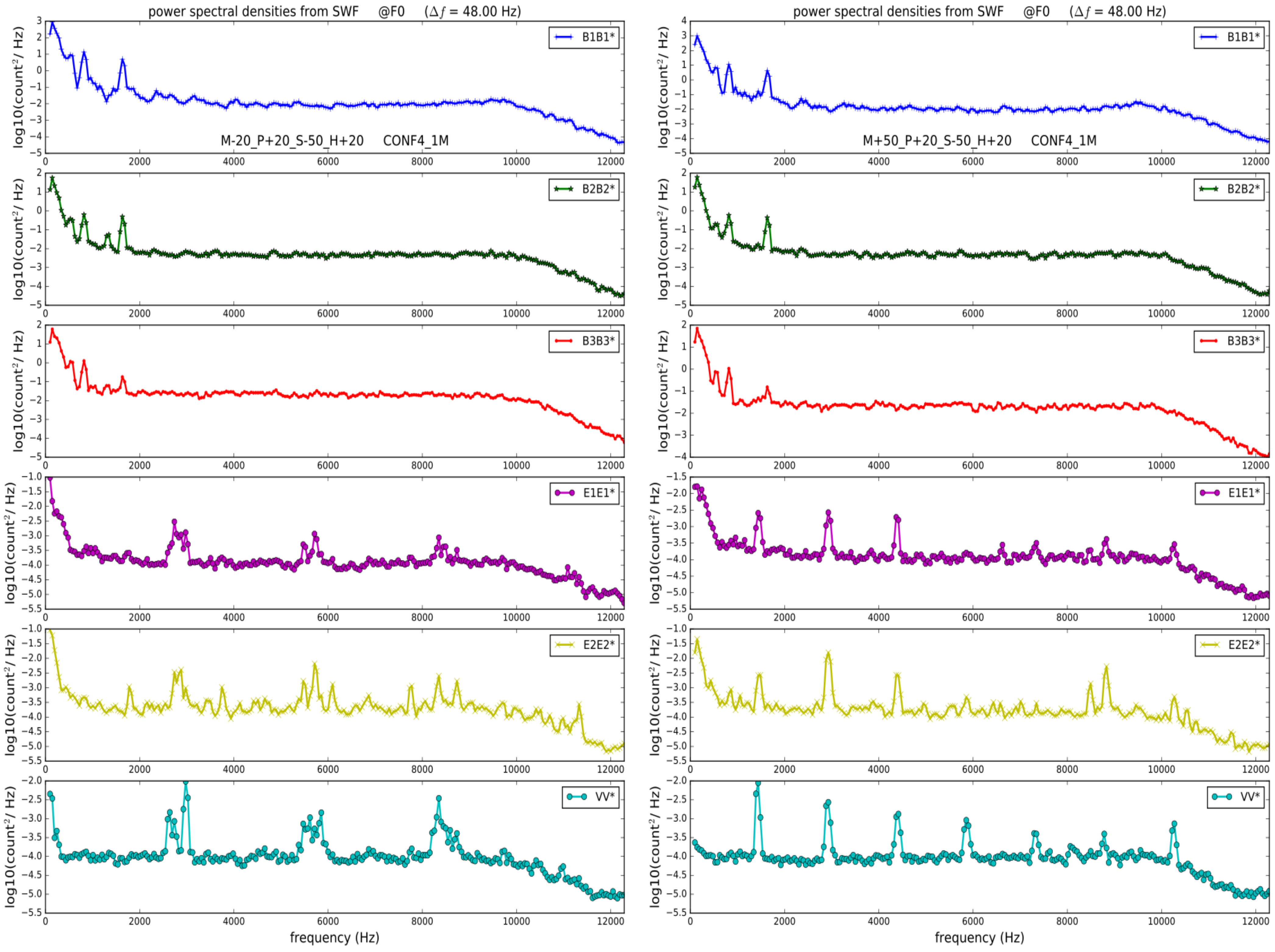
$$\tau = \frac{\Delta\,\phi}{\Delta\,\omega}\,\frac{(\mathrm{rad})}{(\mathrm{rad/s})} = \frac{\Delta\,\phi}{2\,\pi\,\Delta\,f}$$

tau expected: -1.42 T3, **tau measured: -0.91 T3**, tau correction: +0.51 T3



power spectral densities from SWF @F2 (Δf = 0.50 Hz)
M-20_P+20_S-50_H+20 CONF4_1M
power spectral densities from SWF @F2 (Δf = 0.50 Hz)
M+50_P+20_S-50_H+20 CONF4_1M
B1B1*
B2B2*
B3B3*
E1E1*
E2E2*
VV*
log10(count²/ Hz)
frequency (Hz)


power spectral densities from SWF @F1 (Δf = 8.00 Hz)
B1B1*
M-20_P+20_S-50_H+20 CONF4_1M
B2B2*
B3B3*
E1E1*
E2E2*
VV*
log10(count²/ Hz)
frequency (Hz)
power spectral densities from SWF @F1 (Δf = 8.00 Hz)
B1B1*
M+50_P+20_S-50_H+20 CONF4_1M
B2B2*
B3B3*
E1E1*
E2E2*
VV*
log10(count²/ Hz)
frequency (Hz)


power spectral densities from SWF @F0 (Δf = 48.00 Hz)
M-20_P+20_S-50_H+20 CONF4_1M
M+50_P+20_S-50_H+20 CONF4_1M
B1B1*
B2B2*
B3B3*
E1E1*
E2E2*
VV*
log10(count^2/ Hz)
frequency (Hz)

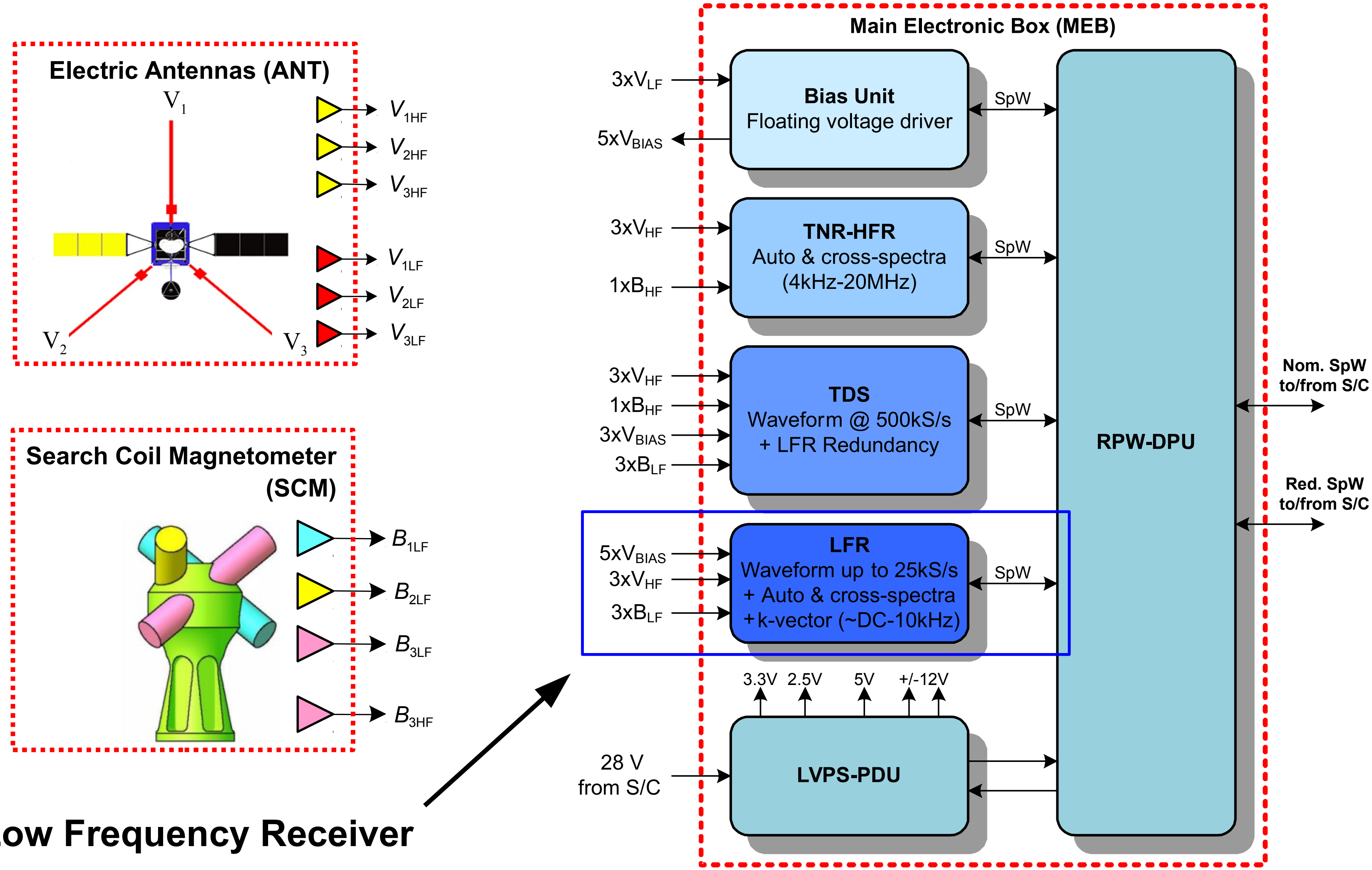
Previous/Updated PFM calibration conclusion

- BIAS TF : ~OK with the *amplitudes* (could be improved for f > 1 kHz ?)
  - => consistent with present LFR simulation results
  - => a *simulated* frequency response on the amplitude may be OK
- SCM TF: not OK with the *amplitudes* (up to ~35% discrepancy at ~1 kHz)
  - => SCM-LFR interface problem …
- Still no analysis done with the *phases*
  - => previous calibration (LESIA, Dec 2016): *partially* OK (telecon Feb 2017)
  - => delta calibration (June 2017): … ?
  - => a *simulated* frequency response on the phase may be OK
- Analyses done with F0, F1, F2 sweep (still not with LF F3)
  - => should be no surprise with LF F3: a *simulated* calibration should be OK
- Still no analysis done on *background levels*
  - => few spectra shown: GSE (artefacts) or real RPW perturbations ?
    no temperature effects ?

Additional slides

RPW Instrument Overview

*Will allow the characterization of the electric and magnetic fields associated to the dynamics of the near-Sun heliosphere **from near DC up to 20 MHz***



Low Frequency Receiver

Current set of Basic Parameters

"Instantaneous" 5 x 5 spectral matrix
(256 FFT points)

$$\mathbf{SM}\left(\omega_j^{(m)}\right)=\begin{bmatrix} B_1B_1^* & B_1B_2^* & B_1B_3^* & B_1E_1^* & B_1E_2^* \\ cc & B_2B_2^* & B_2B_3^* & B_2E_1^* & B_2E_2^* \\ cc & cc & B_3B_3^* & B_3E_1^* & B_3E_2^* \\ cc & cc & cc & E_1E_1^* & E_1E_2^* \\ cc & cc & cc & cc & E_2E_2^* \end{bmatrix}$$

Time Averaged Spectral Matrix (ASM)

$$\mathbf{ASM}\left(\omega_j^{(m)}\right)=\frac{1}{N_{SM}^{(m)}}\sum_{k=1}^{N_{SM}^{(m)}}\mathbf{SM}_k\left(\omega_j^{(m)}\right)=\left\langle\mathbf{SM}\right\rangle_{time}$$

***Frequency* average ...**

$$\mathbf{S}\left(\omega_j^{(m)}\right)=\left\langle\mathbf{ASM}\right\rangle_{frequency}$$

... before computations of the BPs (i.e. wave parameters)

Mono-**k** assumption :

	BP1 set 1:	Power spectrum of the magnetic field (***B***)
	BP1 set 2:	Power spectrum of the electric field (***E***)
(Means, JGR, 1972)	BP1 set 3:	Wave normal vector (from ***B***)
(Means, JGR, 1972)	BP1 set 4:	Wave ellipticity estimator (from ***B***)
(Samson & Olson, GJRA, 1980)	BP1 set 5:	Wave planarity estimator (from ***B***)
	BP1 set 6:	X_{SO}(radial)-component of the Poynting vector
$\mathbf{n}\times\mathbf{E}=\frac{\omega}{k}\mathbf{B}$ →	BP1 set 7:	Phase velocity estimator
	BP2 set 1:	Autocorrelations
$\frac{S_{ij}}{\sqrt{S_{ii}S_{jj}}}$ →	BP2 set 2:	Normalized cross correlations

LFR Spectral Frequencies

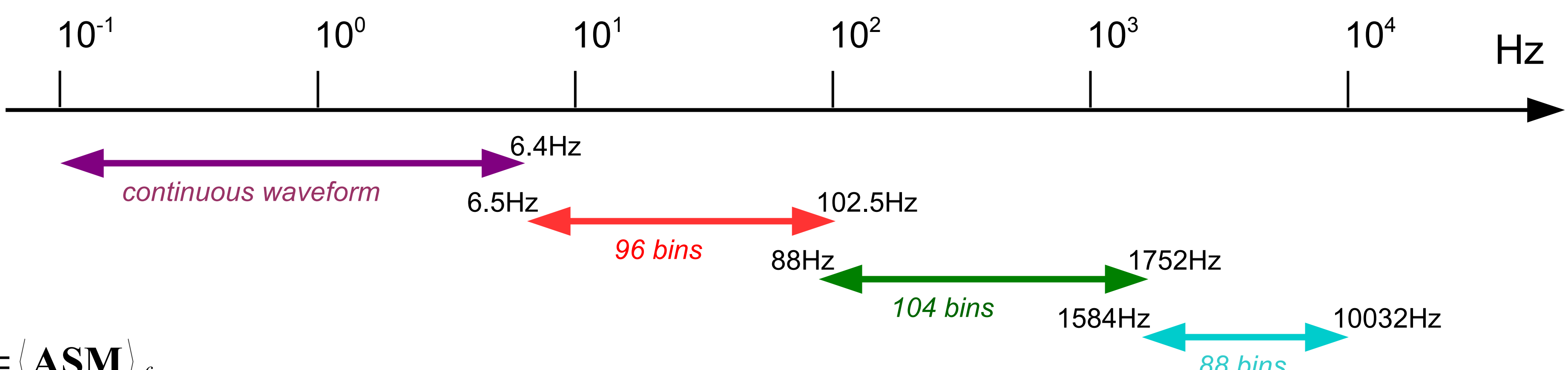
(1) Depending on the frequency channel, **selection** of 96, 104 or 88 consecutive **frequency bins** among 128 (N_{FFT} = 256) of the *time* averaged spectral matrices.

(2) Then, the ASMs are averaged over packets of N_{freq} (8 or 4) consecutive bins :

$$\Delta f^{(m)} = \frac{f_m}{N_{FFT}} \times N_{freq}$$

$$N_{freq} = 8$$

f_3 = 16 Hz	=>	waveform	[DC, 8Hz]		f_3 / 2.5 = 6.4 Hz
f_2 = 256 Hz	=>	12 frequencies	[6.5Hz, 102.5Hz]	$\Delta f^{(2)}$ = 8 Hz	f_2 / 2.5 = 102.4 Hz
f_1 = 4096 Hz	=>	13 frequencies	[88Hz, 1752Hz]	$\Delta f^{(1)}$ = 128 Hz	f_1 / 2.5 = 1638.4 Hz
f_0 = 24576 Hz	=>	11 frequencies	[1584Hz, 10032Hz]	$\Delta f^{(0)}$ = 768 Hz	f_0 / 2.5 = 9830.4 Hz

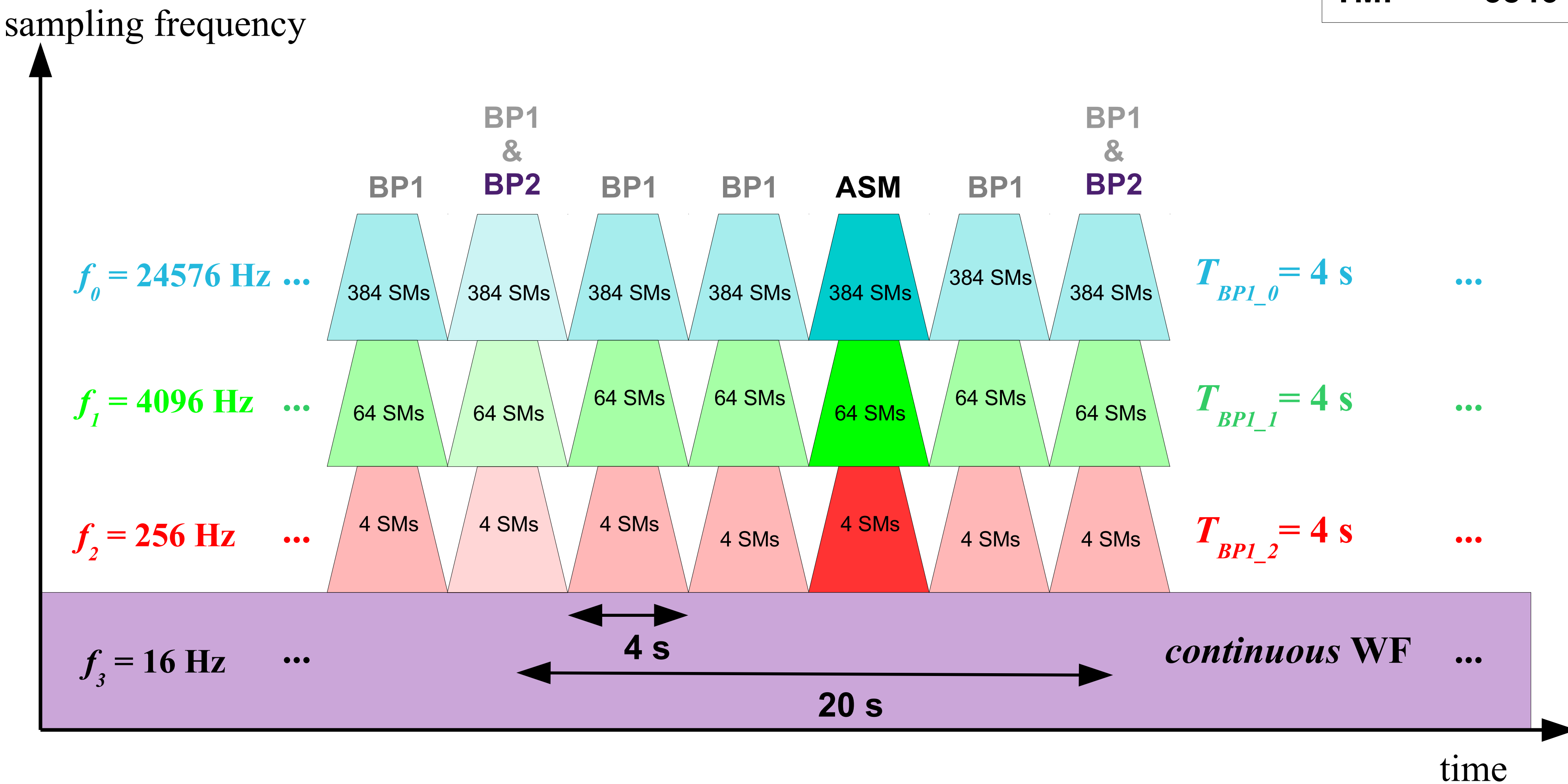


$$\mathbf{S} = \langle \mathbf{ASM} \rangle_{frequency}$$

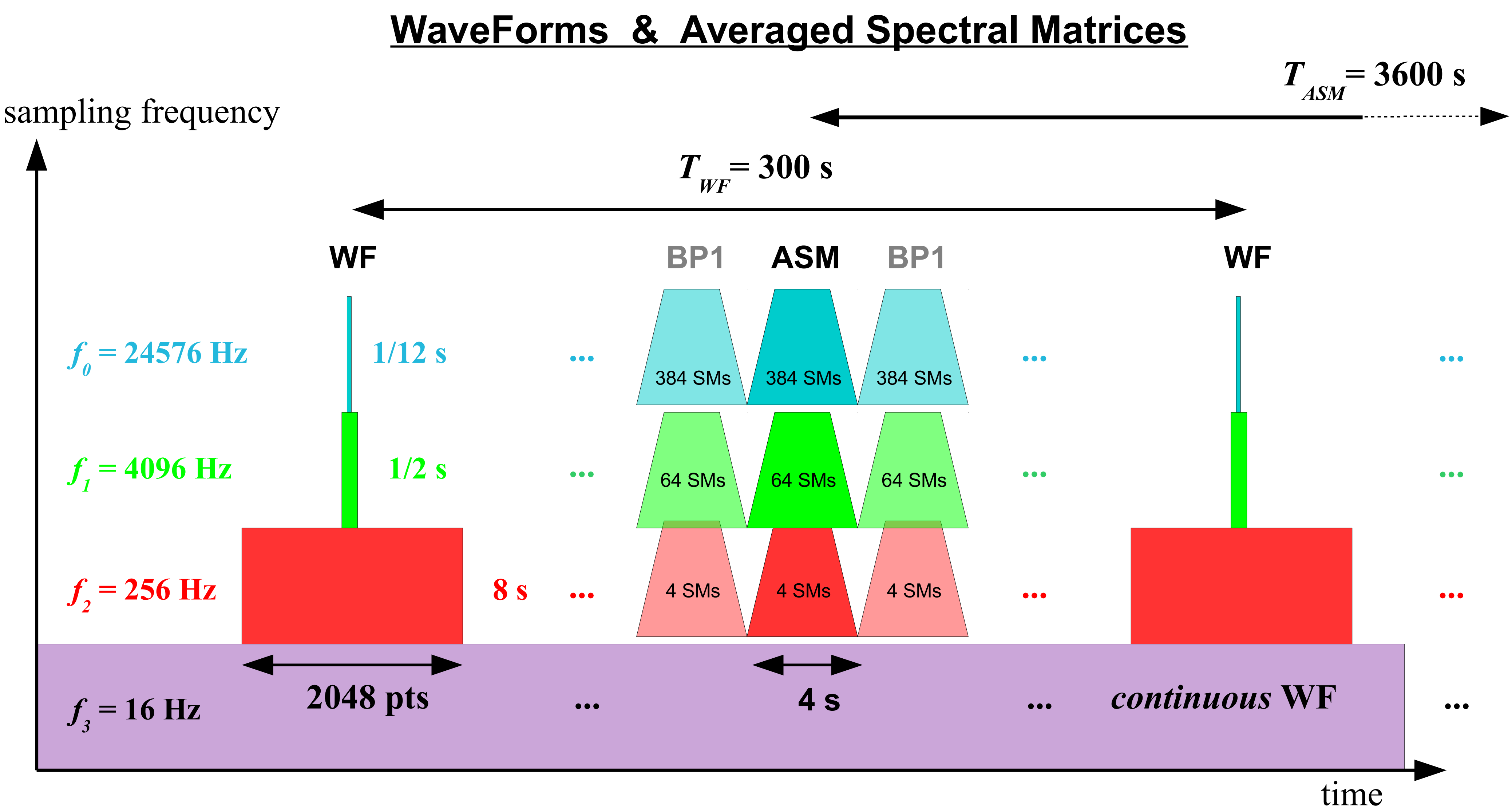
LFR Normal Mode (1)

BP:	**1080 bps**
WF:	**2734 bps**
ASM:	**32 bps**
TM:	**3846 bps**

Basic Parameters

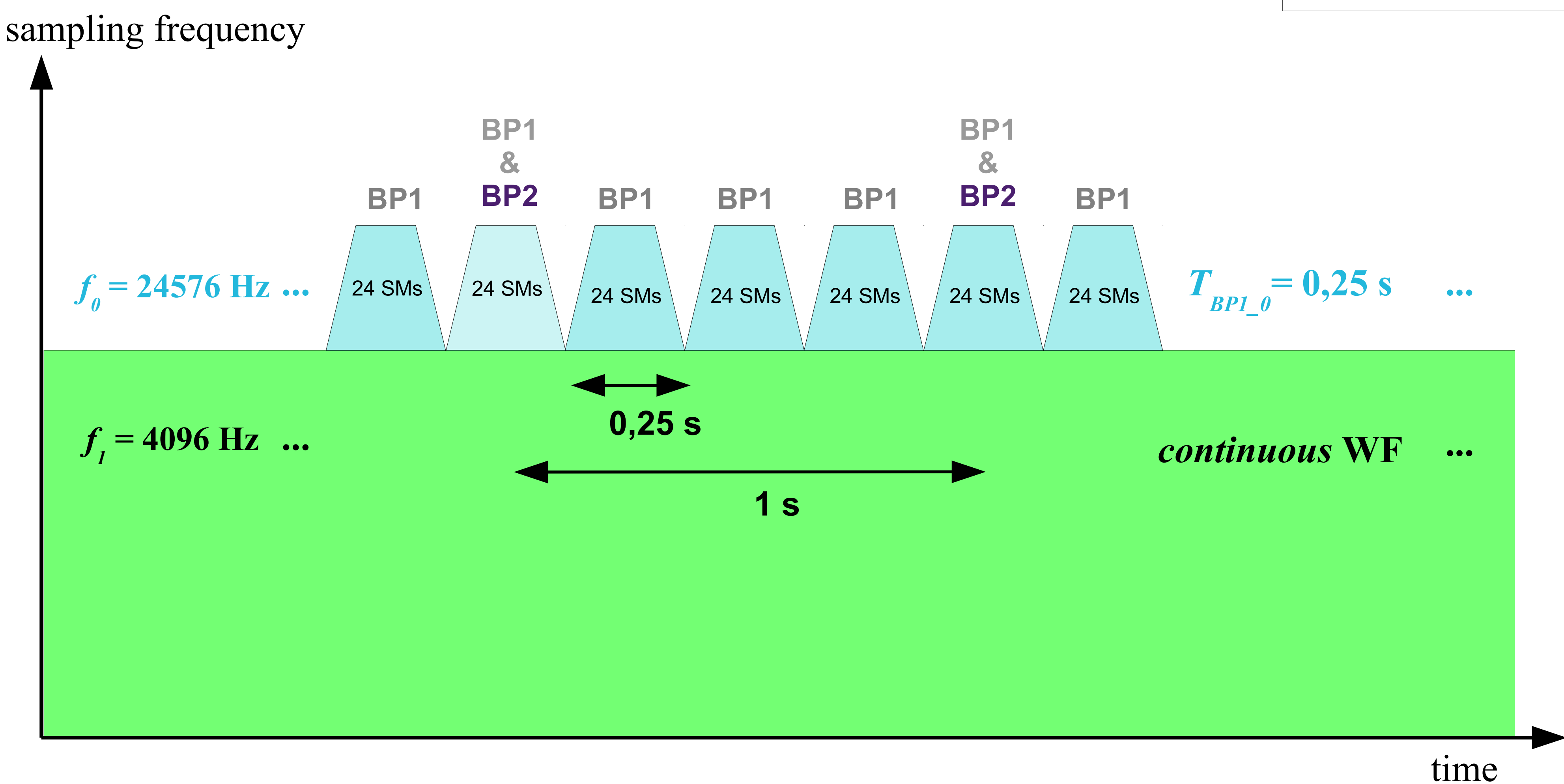


LFR Normal Mode (2)



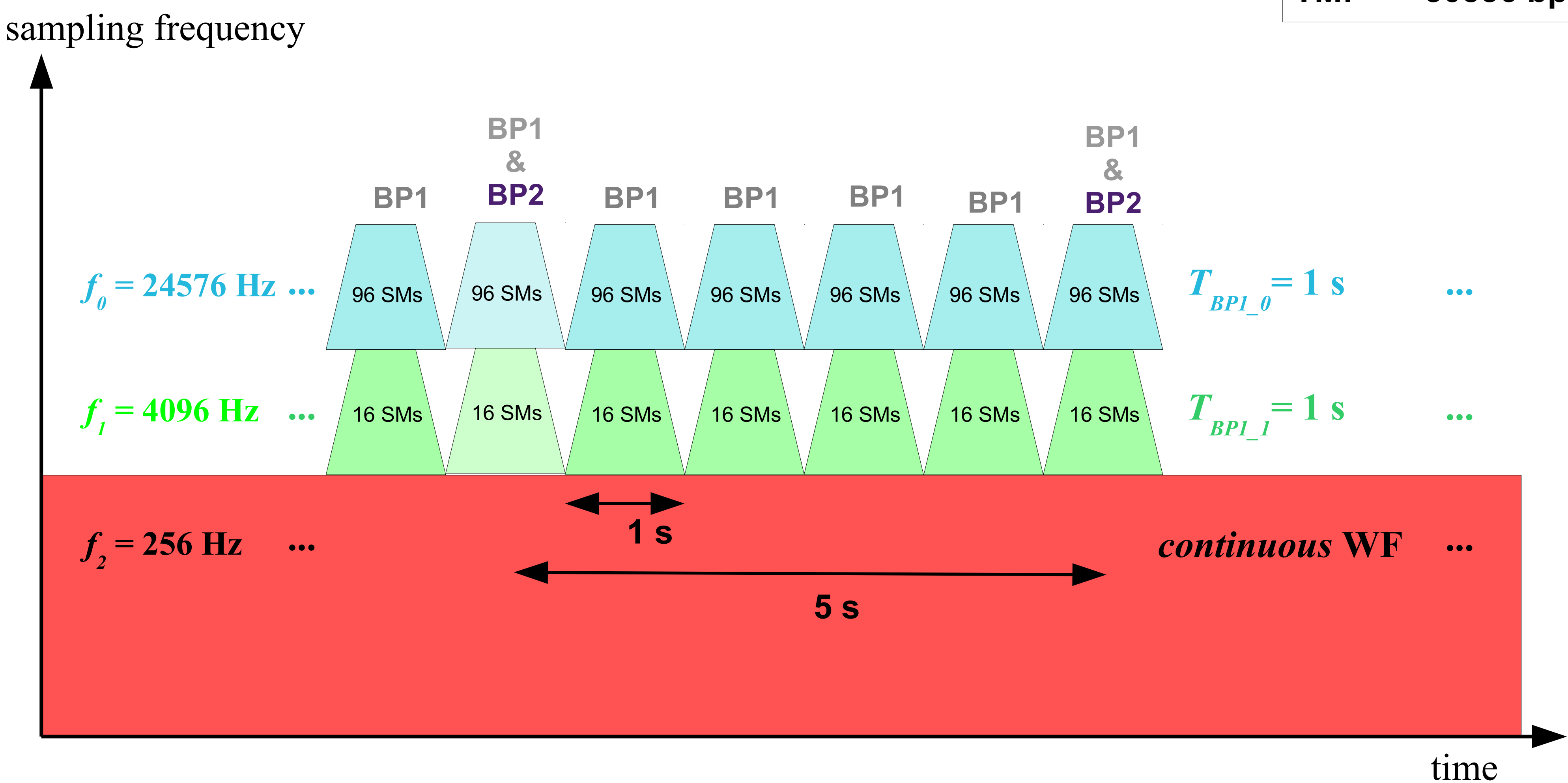
LFR Selected Burst Mode 1

BP:	12672 bps
WF:	393216 bps
ASM:	0 bps
TM:	405888 bps

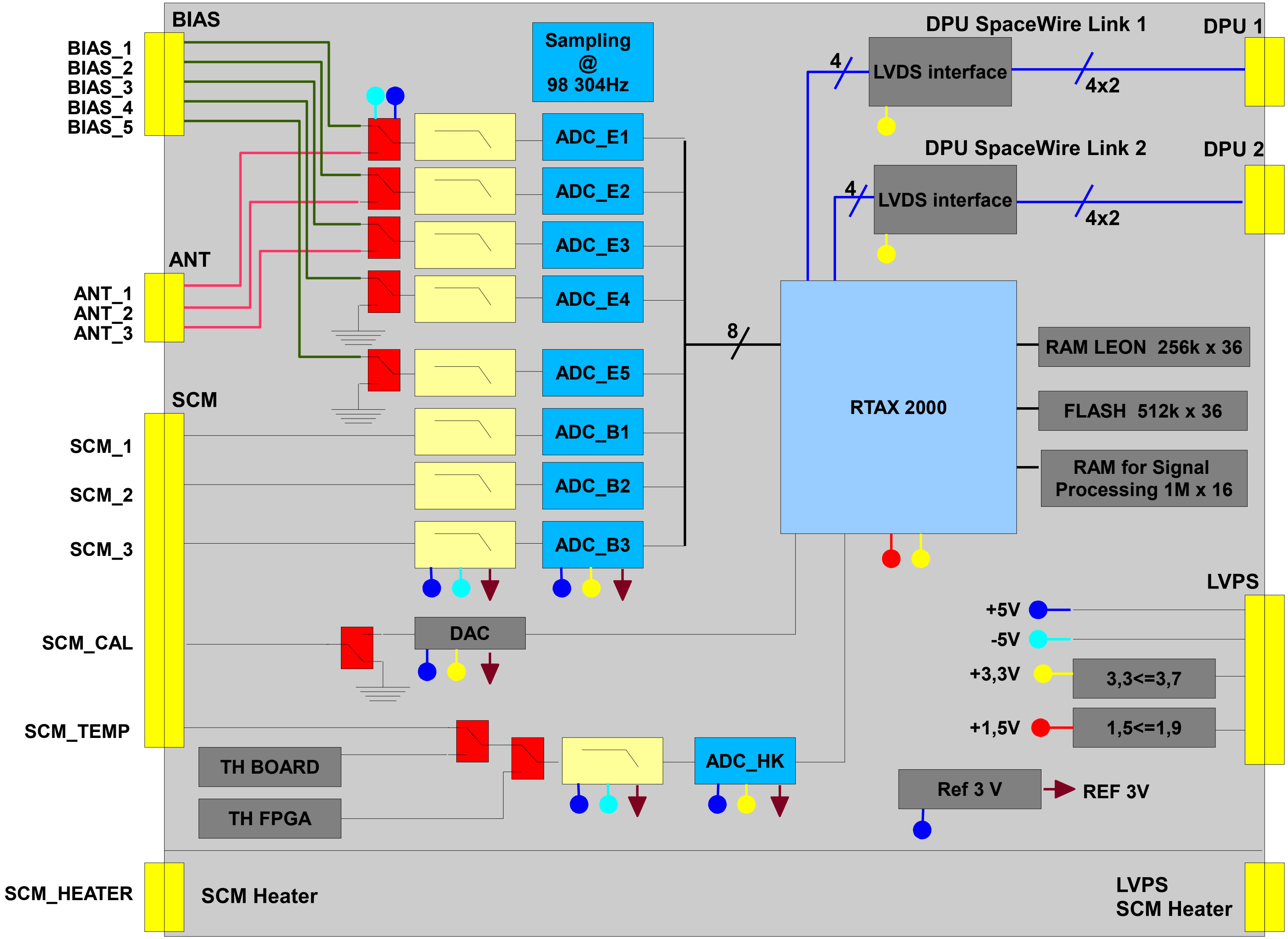


LFR Selected Burst Mode 2

BP:	5760 bps
WF:	24576 bps
ASM:	0 bps
TM:	30336 bps



LFR block diagram



BIAS configuration

BIAS_WORKS								
BIAS_1	BIAS_2	BIAS_3	BIAS_4	BIAS_5				
V1_DC	V12_DC	V23_DC	V12_AC	V23_AC	standard	SCM_1	SCM_2	SCM_3
V2_DC	V3_DC	V23_DC	V12_AC	V23_AC	probe 1 fails	SCM_1	SCM_2	SCM_3
V1_DC	V3_DC	V13_DC	V13_AC	V23_AC	probe 2 fails	SCM_1	SCM_2	SCM_3
V1_DC	V2_DC	V12_DC	V12_AC	V23_AC	probe 3 fails	SCM_1	SCM_2	SCM_3
V1_DC	V2_DC	V3_DC	V12_AC	V23_AC	offsets saturate V12	SCM_1	SCM_2	SCM_3
BIAS_FAILS								
VHF_1	VHF_2	VHF_3	GND	GND		SCM_1	SCM_2	SCM_3
↓	↓	↓	↓	↓		↓	↓	↓
ADC_ E1	ADC_E2	ADC_E3	ADC_E4	ADC_E5		ADC_B1	ADC_B2	ADC_B3