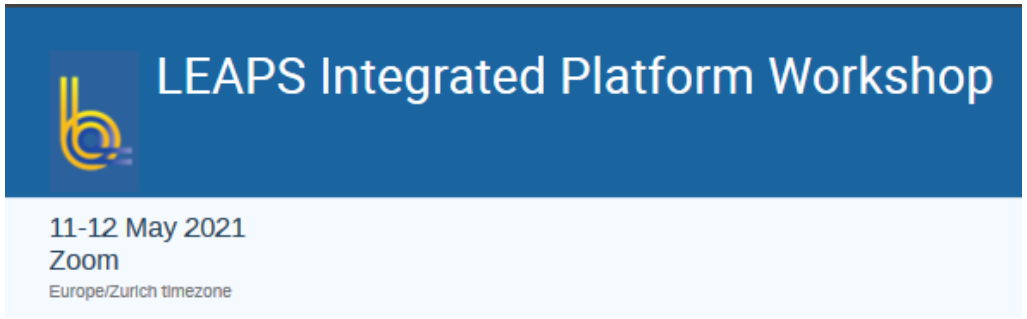


Beam Instrumentation Simulation System v2

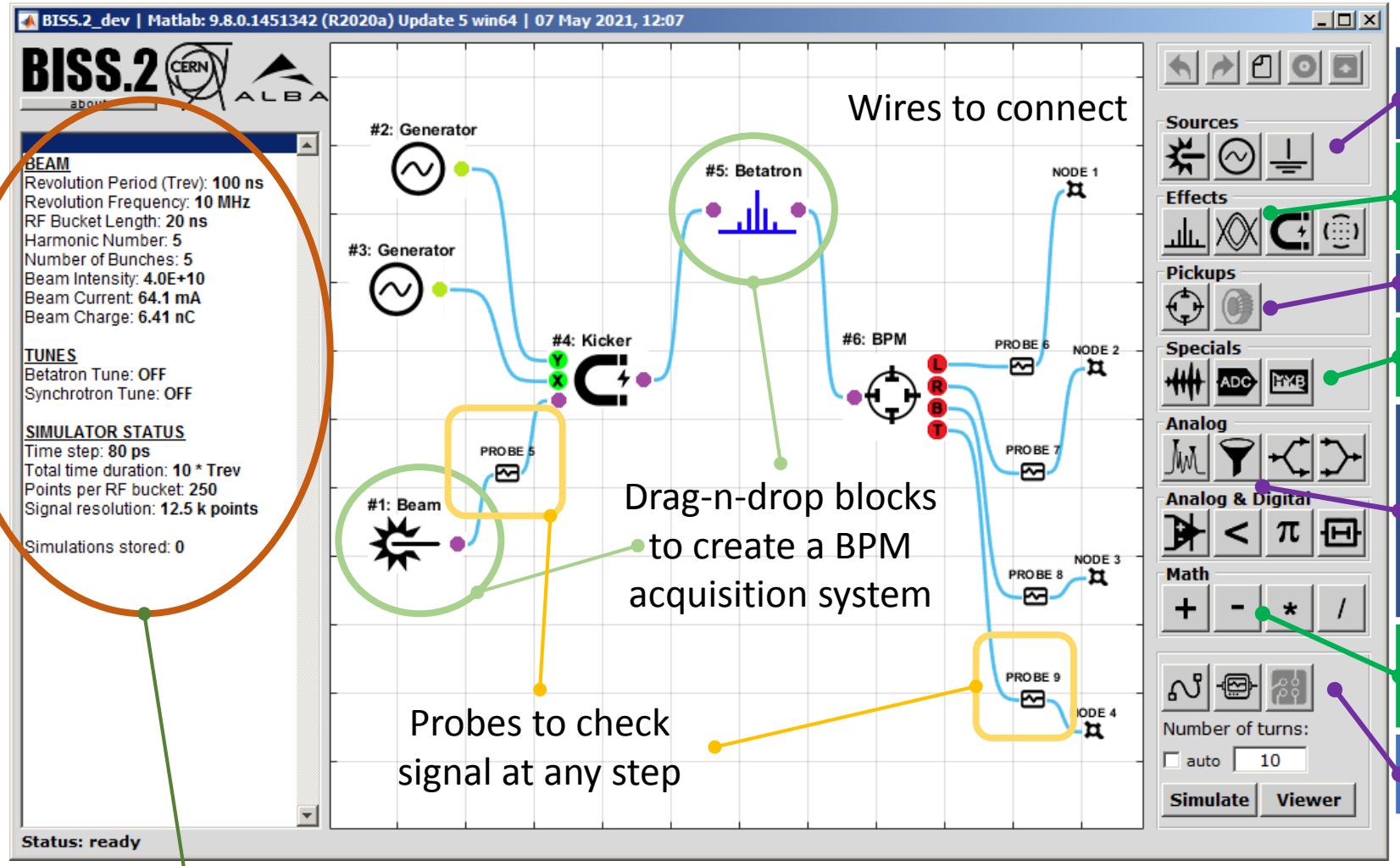
Educational software for Advanced CAS Beam Diagnostics hands-on course

Developed by Andriy Nosych (ALBA-CELLS, Spain)
under collaboration with CERN-BI (M. Gasior, R. Jones)

Based off BISS v1 (Georgios Voulgarakis, CERN-BI 2014)

Target release: eof 2021, CAS schools 2022+
Requires Matlab Runtime (compiled app)

BISS.2 Drawing Board (main window)



Beam parameters, Time & Freq scales, signal resolution, simulation status, etc.

Beam
Generator
Ground
— Signal sources

Betatron excitation
Synchrotron excitation
Kicker
Position sweep
— Beam effects

BPM
BCM
— Pickups

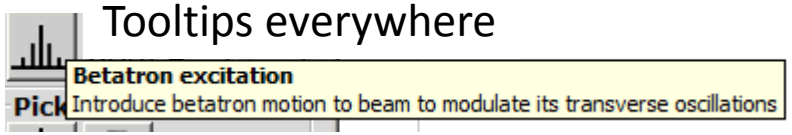
Add noise
ADC converter
Hybrid
— Signal transforms

Peak detector
Filter
Signal splitter
Signal combiner
Amplifier
Comparator
Operator
Delay
— Signal processing

Add
Subtract
Multiply
Divide
— Signal math

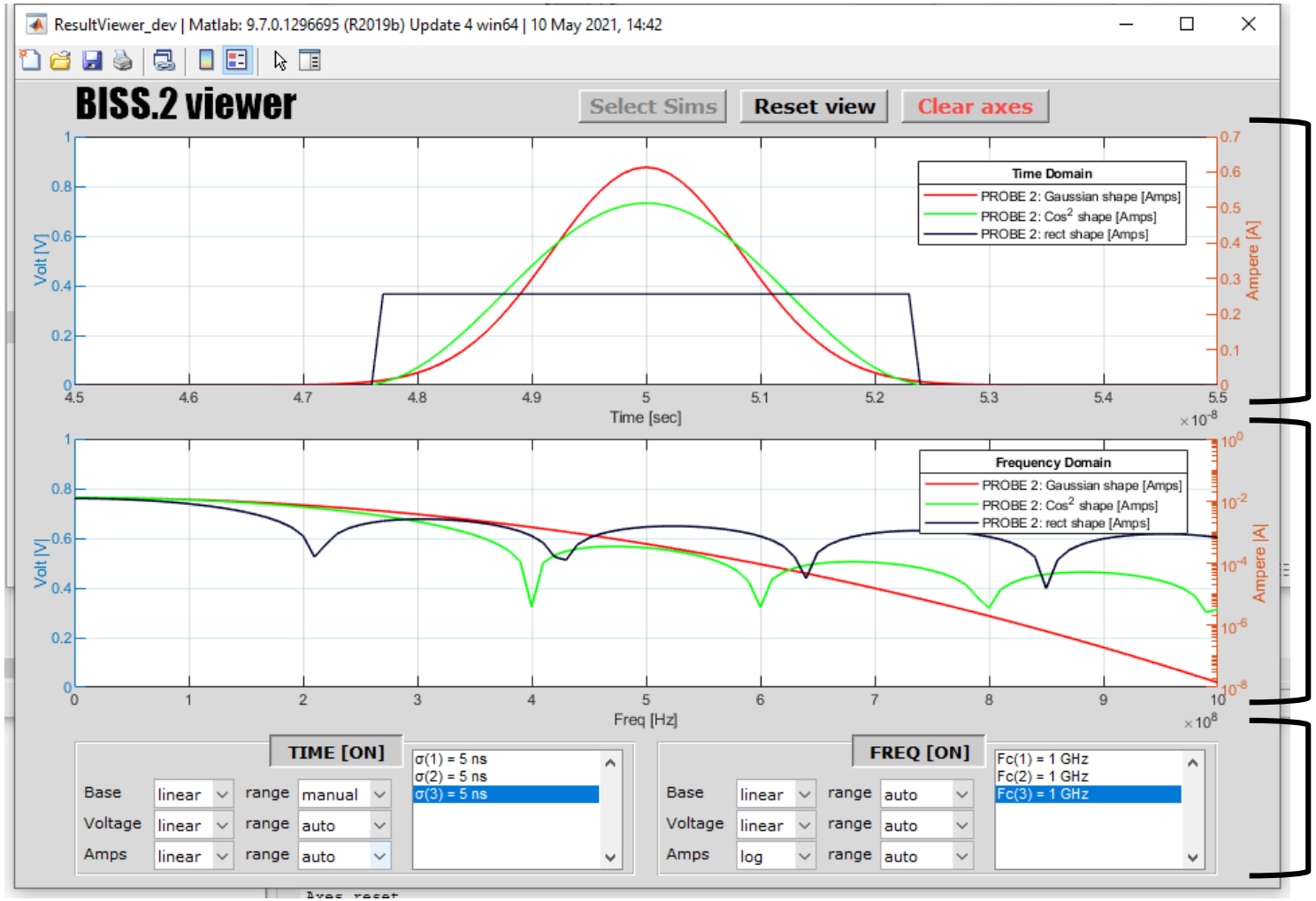
Add Wire
Add Probe
Add Subsystem
— Connect elements

Tooltips everywhere



Development version

BISS.2 Result Viewer

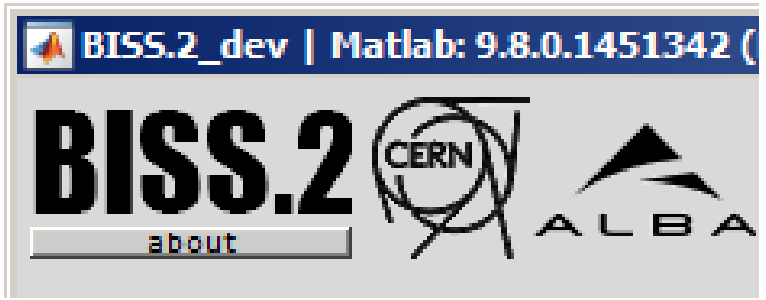


Time Domain
Evolution of signal at every Probe

Freq Domain
Signal magnitude spectrum at every Probe

Axes controls
Scales, range, key values

Development version



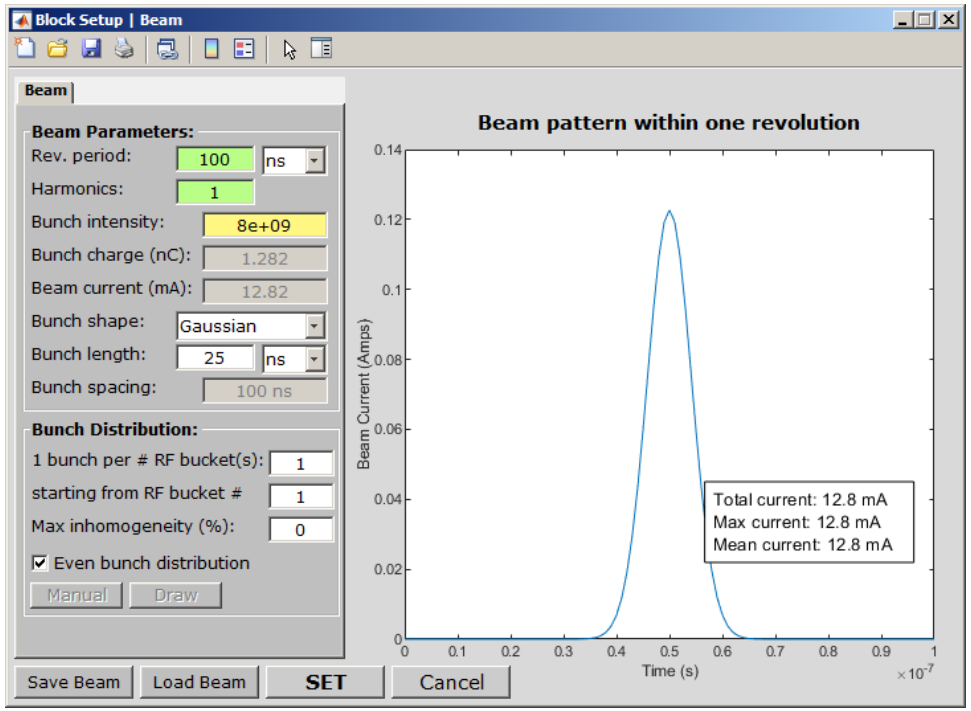
Some workbook and classroom examples

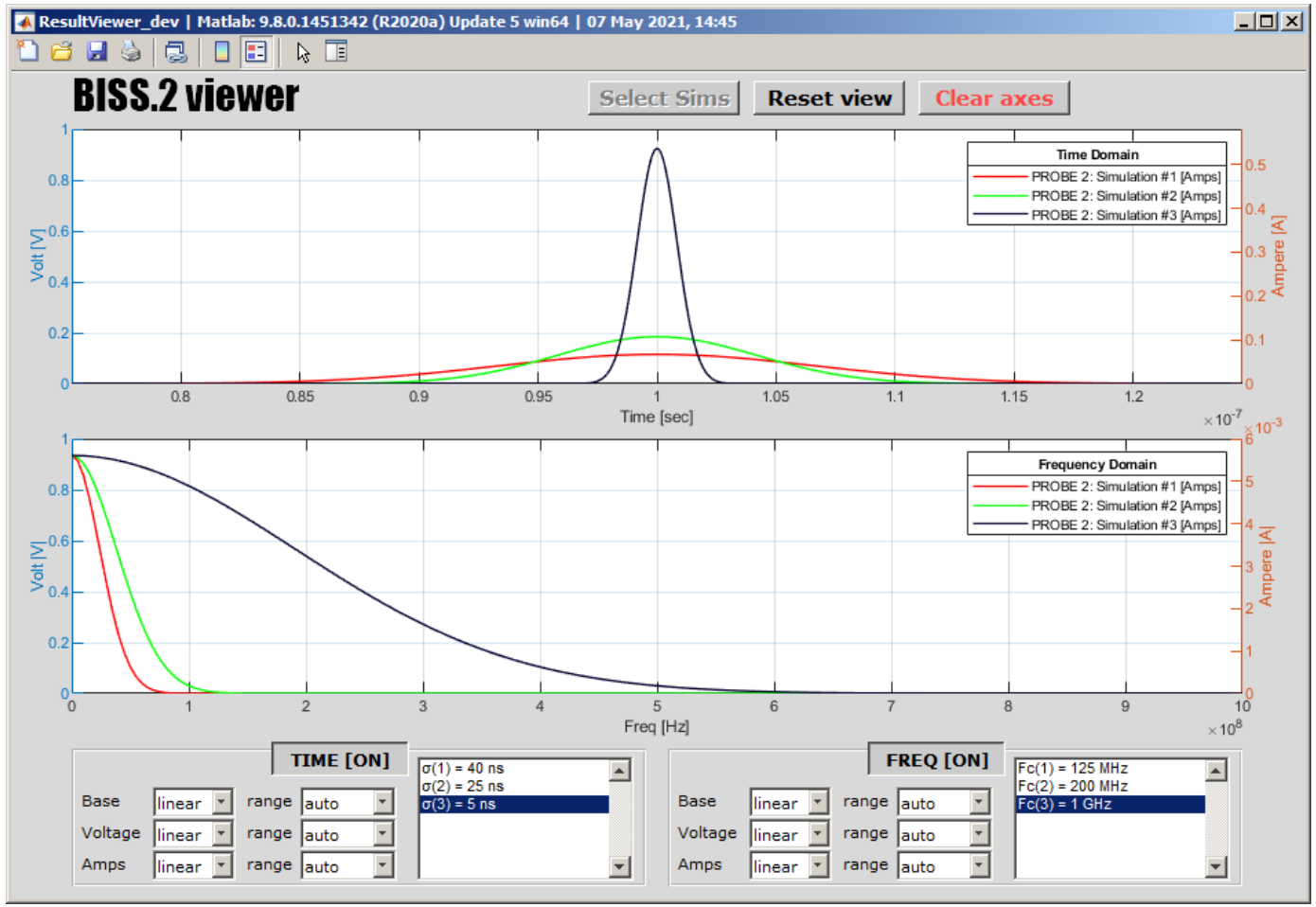
Understanding a Bunch in Time and Freq domains

Exercise

What happens to the frequency content of the signal if we increase the bunch length to

a) 40ns
b) 25ns
c) 5ns



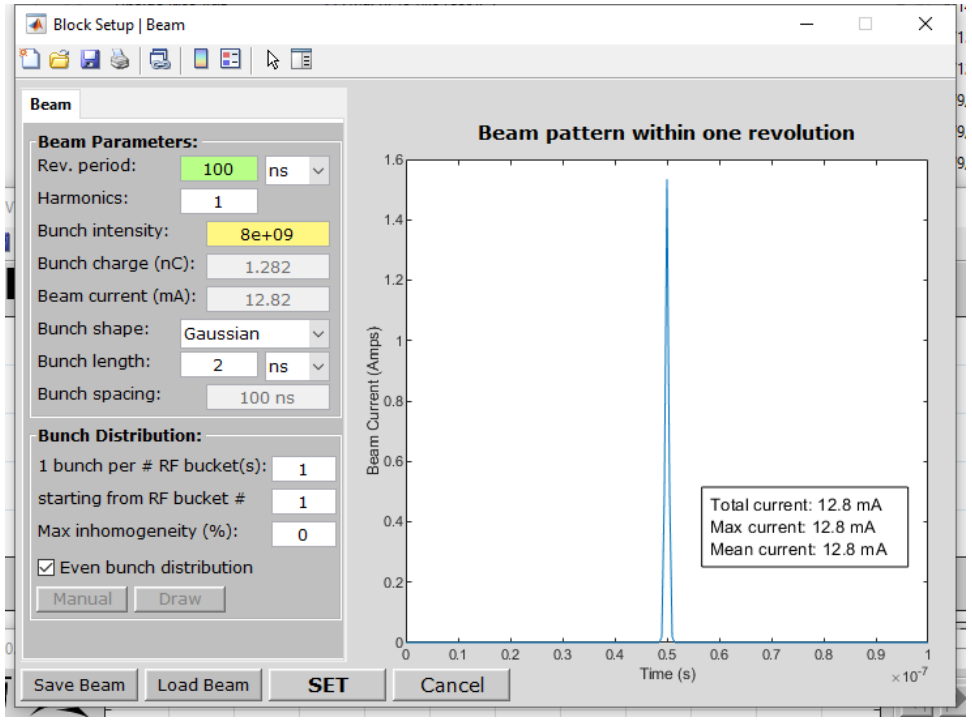


Understanding a Bunch in Time and Freq domains

Exercise

How is frequency associated with changing

a) harmonic number of the beam



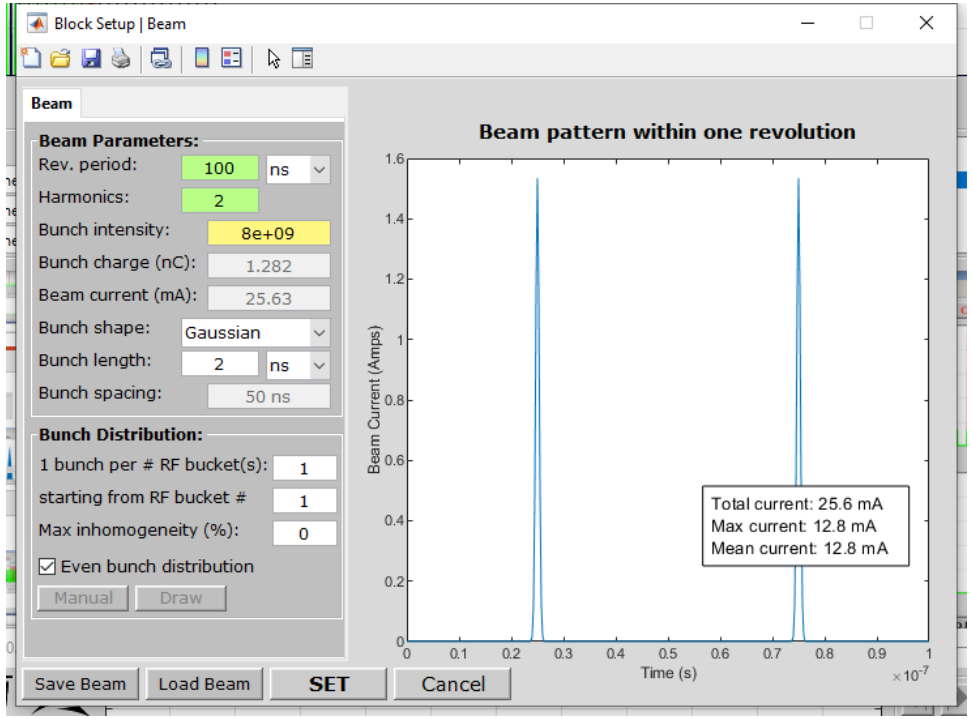
Understanding a Bunch in Time and Freq domains

Exercise

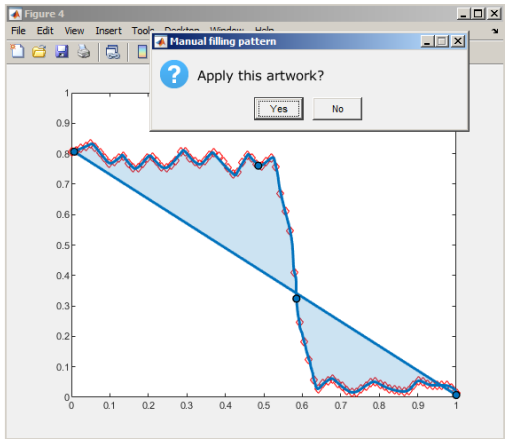
How is frequency associated with changing

b) its charge

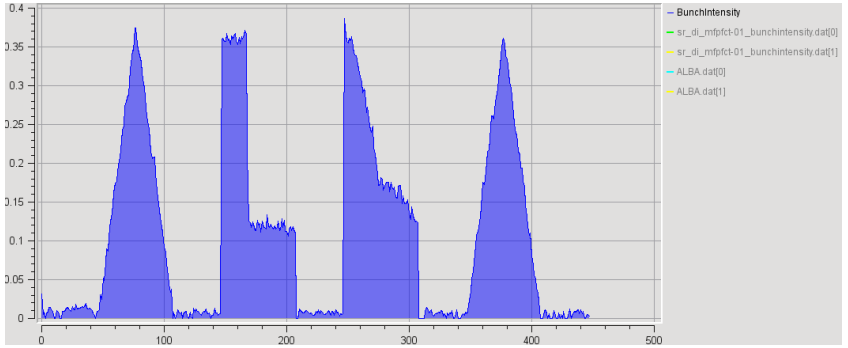
c) number of turns



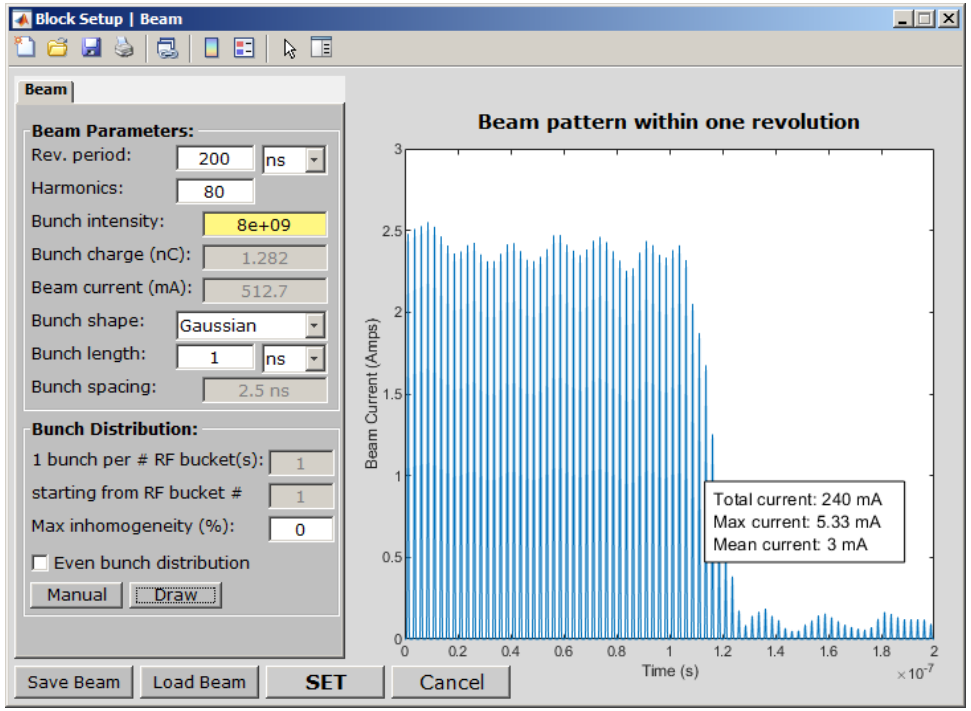
Create custom filling patterns

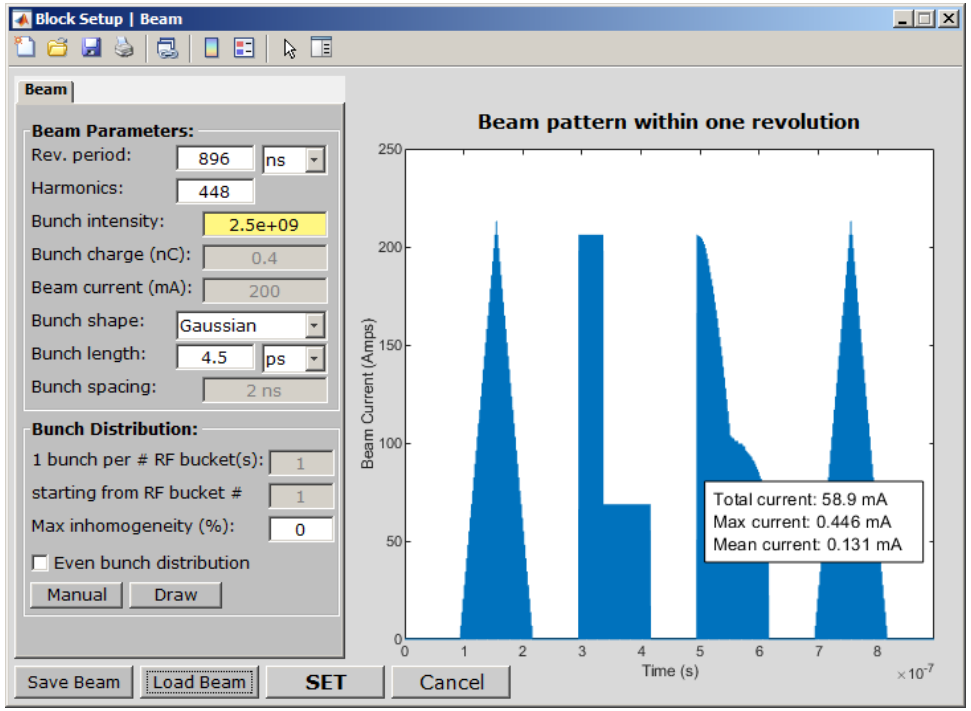


Draw beam patterns

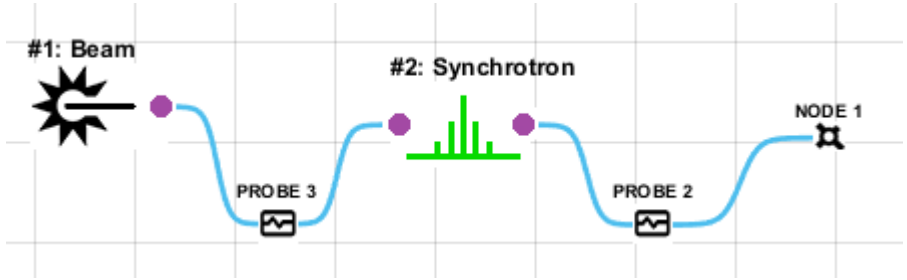


Save\load beam patterns



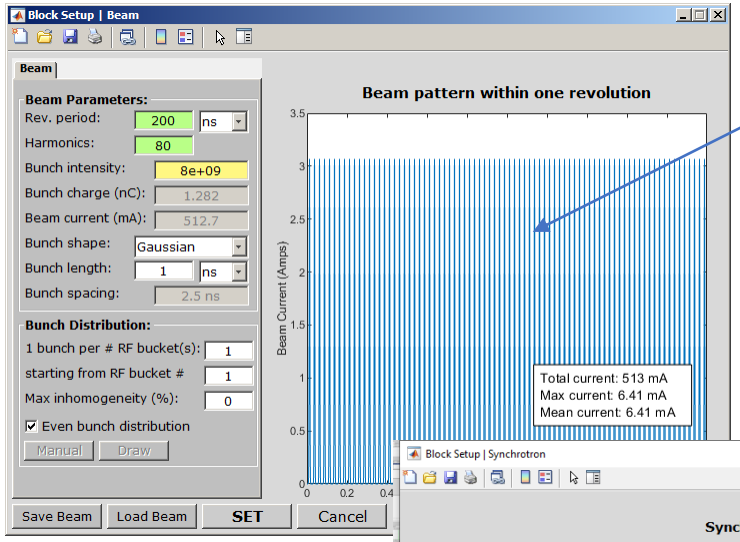


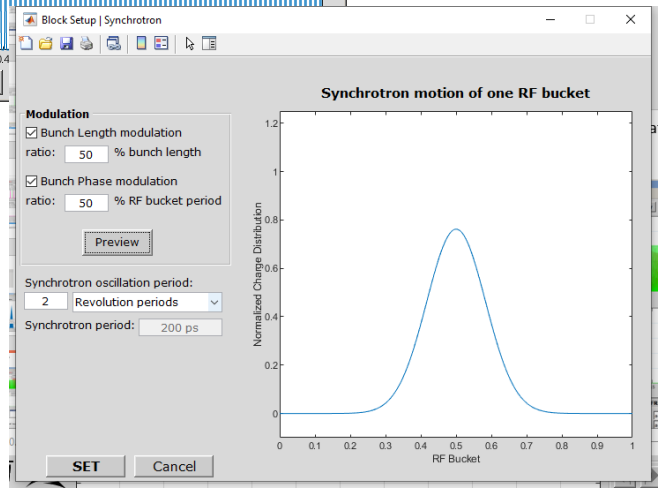
Synchrotron excitation with bunch length and bunch phase modulation



Exercise

1) Study the effect of synchrotron bunch motion in Time and Freq domains.
2) What is the particular difference in Freq domain and why?

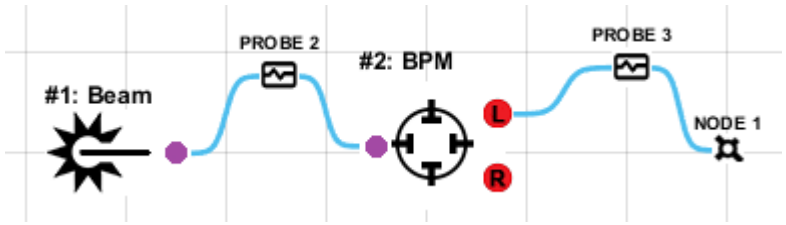




6 turns of this

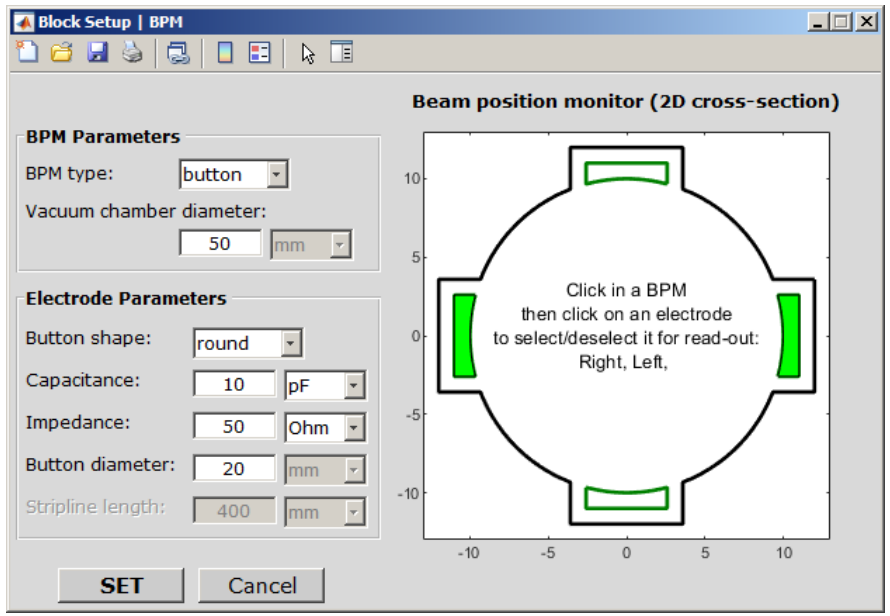
result in this

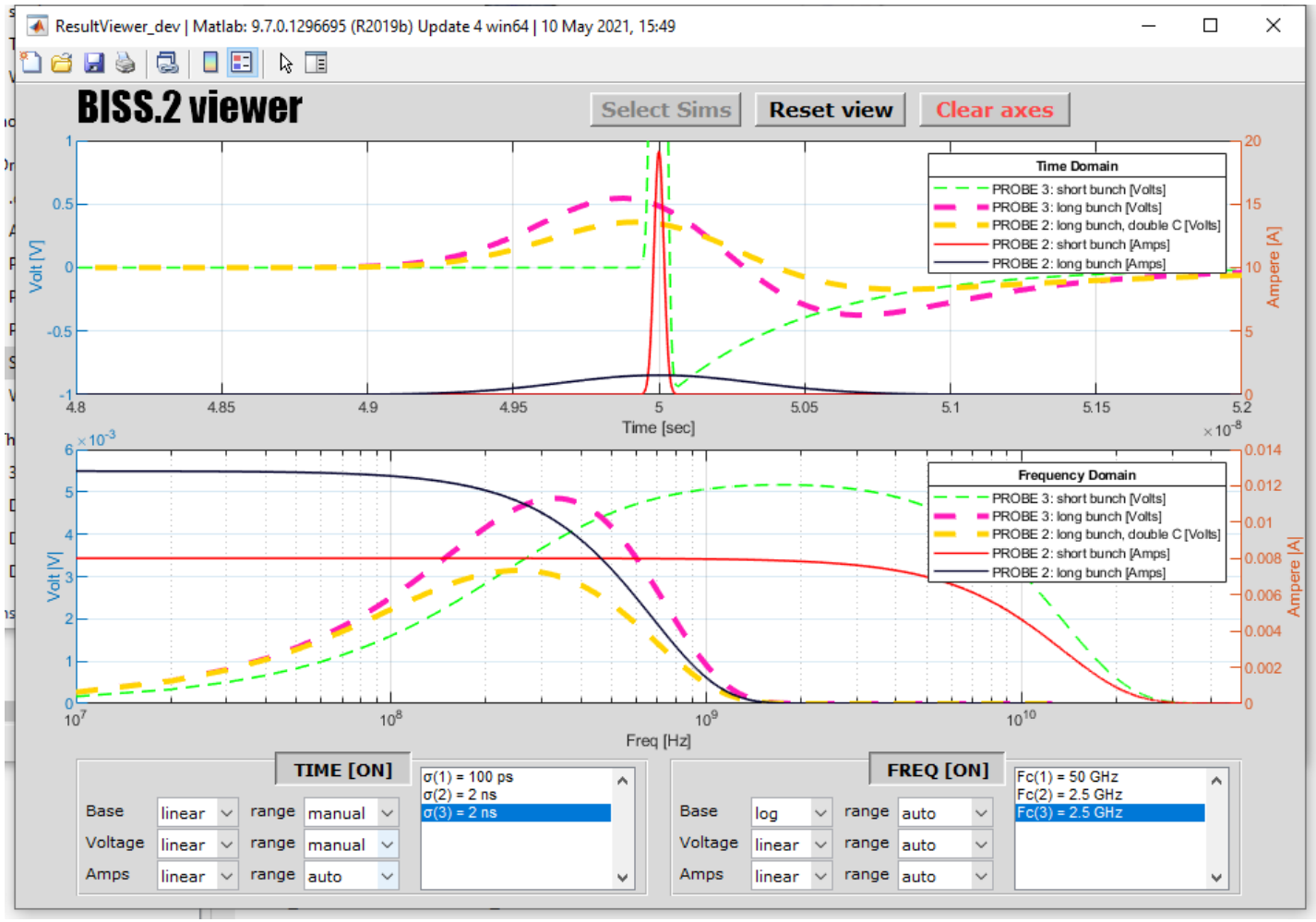
BPM signal dependence on beam and electrode parameters



Exercises:

1) Describe the response of a button electrode to a beam excitation.
2) How do the following affect the Time and Freq output in terms of amplitude and signal shape:
   a) Area of button electrode, b) Button Capacitance, c) Termination resistance.
3) What is the difference in acquiring a short single bunch and a long one with a BPM?

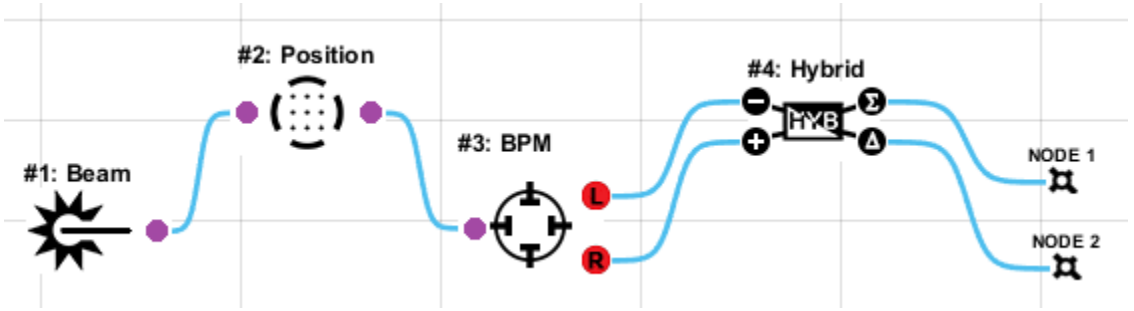




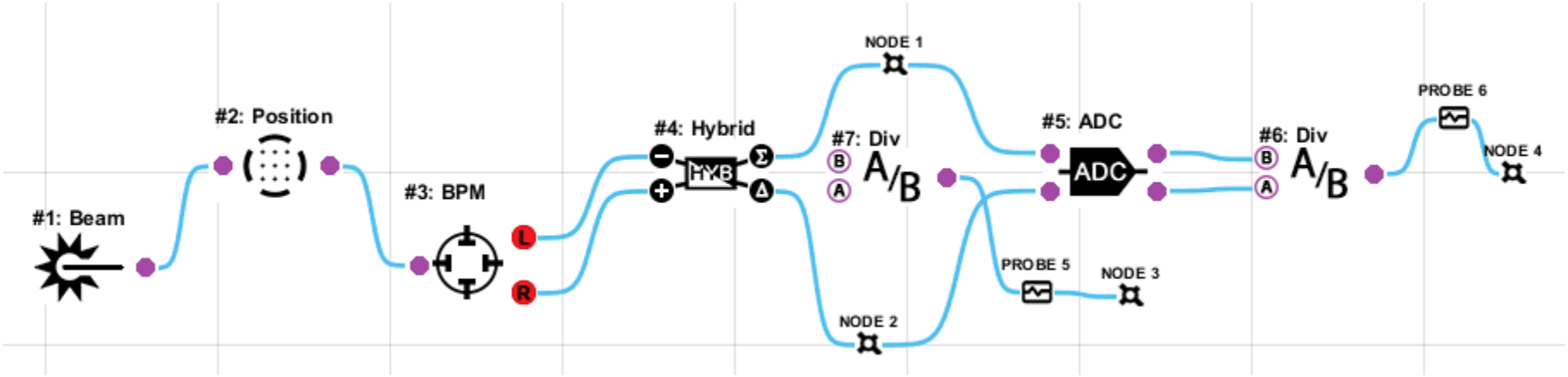
Transfer impedance and low freq cutoff define a BPM:

$$Z_T = \frac{A}{2\pi r \times c \times C_e} \qquad f_L = \frac{1}{2\pi R C_e}$$

More complex circuits

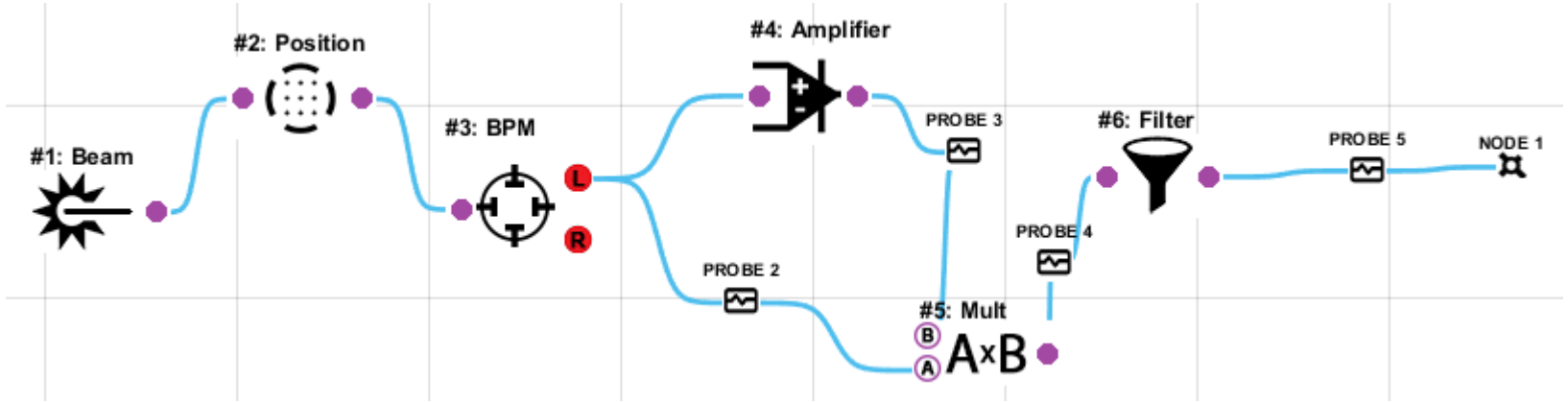


Hybrid device for signal Difference and Sum.



ADC to digitize Diff and Sum for division.

Compare analogue and digital result of division.



Homodyne mixer for continuous beam.

Filter retains the DC component of the signal.

Other exercise examples

BPM button design
Construct a button electrode with impedance 50 Ohm, providing 100mV peak signal for a 2ns bunch of 5e9 charges.

Study horizontal Beam Sweep with a 100MHz RF structure comprised of 2ns bunches at 100 turns. What do you notice about the output of BPM electrode signals?

Understanding ADC
To what voltage difference does the least significant bit of the ADC correspond (i.e. an increment of 1 when representing the ADC output in decimal)?

At what bunch intensity does the circuit saturate for large position offsets?

How many bits do we need to have a resolution of 190 um for a maximum bunch intensity of 5e9?

Build homodyne circuits with amplifiers
Create a homodyne circuit with a limiting amplifier to produce a square wave from the input signal.

What are the parameters of your amplifier to obtain such a signal?

Mixers and Filters
Create a homodyne mixer using a multiplication block. What do you observe about the frequency content before and after the mixer?

What does the response time of the filter depend on? What is the ratio of your DC component to the first harmonic?

Thank you!

Acknowledgements:
Rhodri Jones, Marek Gasior, Manfred Wendt
Francis Perez, Ubaldo Iriso

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BISS v1
OASYS - OrAnge SYnchrotron Suite
Adobe Photoshop interface
Lecroy scope interface