ANALOG SIGNAL PROCESSING FOR ELECTROSTATIC BPMS ON CERN'S PS BOOSTER

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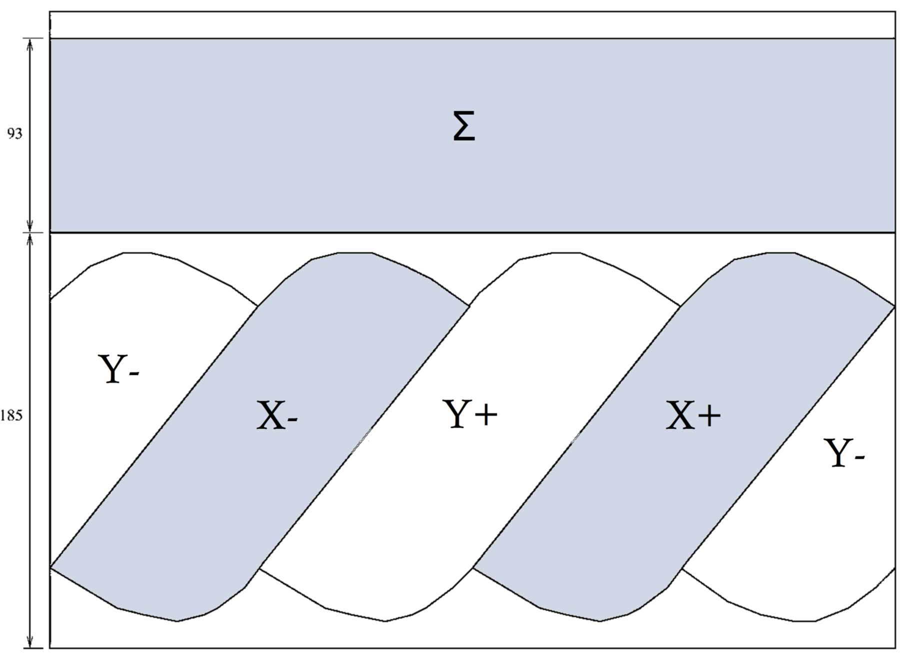
Abstract

The PS Booster is a synchrotron consisting of 4 superimposed rings of 50 m in diameter. The beam is injected from CERN's LINAC 2 and is then bunched by the booster's RF acceleration system. With the installation of LINAC 4, the injected beam will be bunched, allowing a turn by turn trajectory measurement system to be developed. This will replace the older orbital measurement system. Along with these upgrades, the signal processing hardware must be extensively changed to optimise the signals extracted from the beam position monitors. This includes new passive hybrid circuitry, ultra low noise, wide-band, variable gain amplifiers, along with remote control hardware and software.

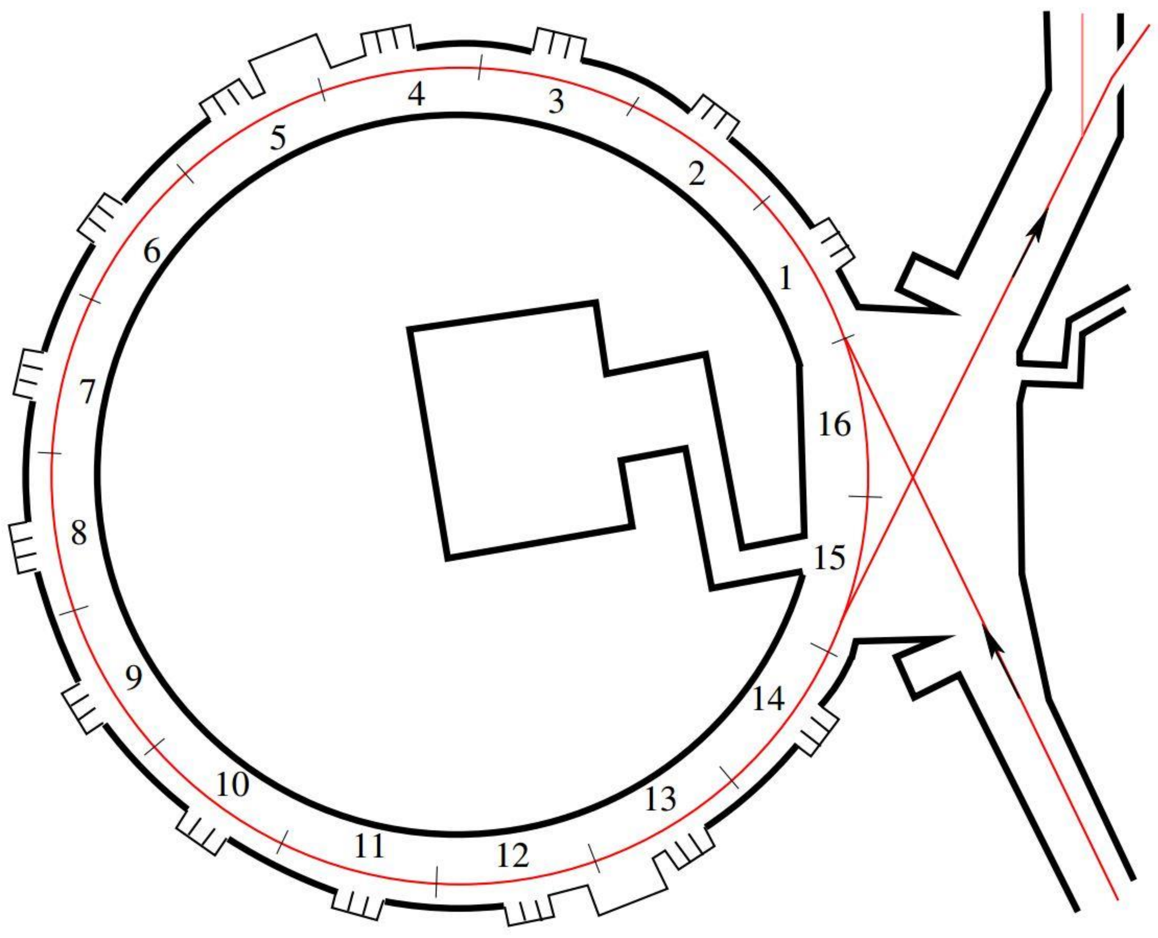
Booster BPM Electrodes and Properties [1]



Electrode aperture	140 mm
Σ electrode length	90 mm
Σ electrode capacitance	220 pF
Δ electrode length	180 mm
Δ electrode capacitance	110 pF
Displacement sensitivity (Δ/Σ = 1)	50 mm
Mid-band transfer impedance	170 mΩ

- 16 BPMs on each ring, 64 in total
- Separate dedicated ∑ electrode

Booster with BPM positions, injection and ejection lines



PSB Beam properties [2]

- Intensity range: 5e9 – 2.5e13 p/b
- 4σ bunch length: 75 – 250 ns
- Beam Current 20 mA – 20 A (peak)
- f_{rev}: 600 kHz – 1.83 MHz

BPM signal extraction

Radiation environment:

- 10 kGy/year dose rate at the vacuum chamber level
- 1 kGy/year dose rate on the floor [3]
  - No active components in the tunnel

Vacuum tubes:

- More resilient to radiation in comparison to other active components.

Disadvantages:

- They are mostly obsolete
- Sensitive to magnetic fields
- Need replacing every 1-2 years

Passive extraction options: [4]

- If a load with impedance Z, is connected to an electrode with capacitance C, then the lower cut off frequency is defined as:
  - $f_c = \frac{1}{2\pi ZC}$

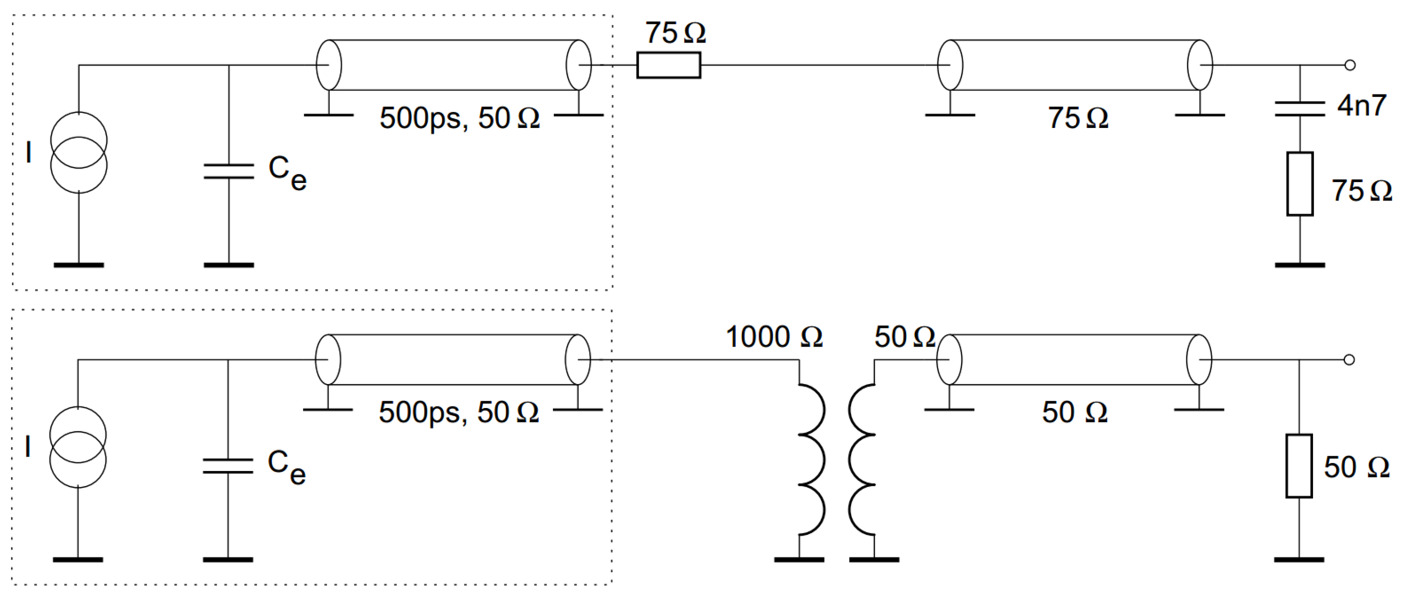
Connecting a terminated 50 Ω cable directly to a BPM is unfavourable as the lower cut off frequency will be ~15 MHz. Most of the energy in the beam spectrum is below this cut off.

Frequency dependant loading:

- It maintains a high impedance for the lower frequencies, while terminating the cable at higher frequencies

Disadvantages: [5]

- The next stage will require a high input impedance
- Low end signals will still be heavily attenuated
- Response correction circuitry will be needed



Head Electronics

The decided extraction technique was to use transformers to change the impedance seen by the electrodes.

- It sacrifices the high frequency response for an improvement at the low end
- Can also serve as a hybrid to create Σ and Δ signals
  - This is advantageous as it minimises the amount of sensitive matched circuitry
- Load impedance 'seen' by Σ electrode is 1 kΩ
  - Lower cut off frequency is ~ 720 kHz

Disadvantages:

- If the impedance transformation is pushed too far, the parasitic elements of the transformer will become noticeable
- Loss of 14 dB, with no gain added until signals have reached the surface, resulting in greater sensitivity to interference
- f_{rev} at injection is 600 kHz, some additional amplifier gain is needed.

References

[1] M. Rabany, "The orbit measurement system of the CERN 800MeV PS Booster", IEEE Trans. Nucl. Sci. 20

[2] J. M. Belleman "A proposal for a trajectory measurement system for the PS Booster" CERN-BE-2010-030

[3] J. M. Belleman "Radiation and electronics in PS and PSB"

[4] G. Schneider, "Method for ultra−wide−band pick−up signal transmission without active electronic elements near the capacitive electrodes", MPS/INT.SR/69−1

[5] J. M. Belleman "A proposal for new-head electronics for the PS orbit measurement system" AB-Note-2003-057

Amplifiers and control

- Amplifiers are kept on the surface:
  - No exposure to radiation
  - ~70 MHz bandwidth
  - Gain range; -12 to 60 dB
  - Controllable in 3 dB steps
  - Equivalent input noise density of <1 nV/√Hz
- Gain is controlled via Ethernet
  - The gain of each channel and each BPM can be controlled independently
- There is a NIM module dedicated to each BPM. The NIM module contains
  - 3 amplifiers, one for each of the sum and the difference channels
  - Gain control circuitry
  - Ethernet connectivity