TRIUMF Beam Physics Note
TRI-BN-15-10
July, 2015

Source-HRS Beamline Grounding Requirement versus Frequency

R. Baartman

TRIUMF

Abstract: The ARIEL High Resolution Separator (HRS) grounding requirement is quite stringent (< 1 Volt FW) and applies at all frequencies. This note shows that the beamline between the source and the HRS has a more relaxed requirement, but only below about 700 Hz. Above 2kHz, the maximum allowed peak-to-peak voltage is 0.5 Volt

4004 Wesbrook Mall, Vancouver, B.C. Canada V6T 2A3 Tel: 604 222-1047 Fax: 604 222-1074
www.triumf.ca

1 Introduction

In ARIEL, the lack of any energy selection upstream of the HRS means that the fractional energy spread must be small compared to the smallest resolvable fractional mass difference. The energy is 60 keV and the resolution goal is $dm/m = 1/20000$, so the High Voltage error and therefore also the grounding between the HV acceleration and the HRS must be small compared to $60kV/20000 = 3\,$volts for singly-charged ions. In consultation with engineers, we have chosen 1 volt as a reasonably achievable grounding goal, though the smaller, the better[1]. The intervening beamline between the HV acceleration and the HRS can have a ground that is in error by an amount larger than 1 volt because the energy gained is lost again when reaching the HRS. But in principle this argument only applies to fixed voltages; if the grounding fluctuates sufficiently quickly its effects will not cancel but in effect the beamline will operate slightly like a drift tube linac.

2 Theory

Let us model the region between the ion source and the HRS as a drift tube of length L. Its voltage fluctuates sinusoidally with frequency f and amplitude V. Then the energy change from source to HRS slit is:

$$\Delta E = qV[\sin\phi - \sin(\phi - \alpha)], \tag{1}$$

where $\alpha = 2\pi f L/(\beta c)$, $L/(\beta c)$ being the phase change during the flight time. This is largest for $\phi = \alpha/2$, so the most energy gain is $2qV\sin(\alpha/2)$; the most energy loss has opposite sign, so the total effective voltage change is $4V\sin(\alpha/2)$ and this must be less than 1 Volt. Explicitly, referring to peak-to-peak $V_{\mathrm{p-p}} = 2V$:

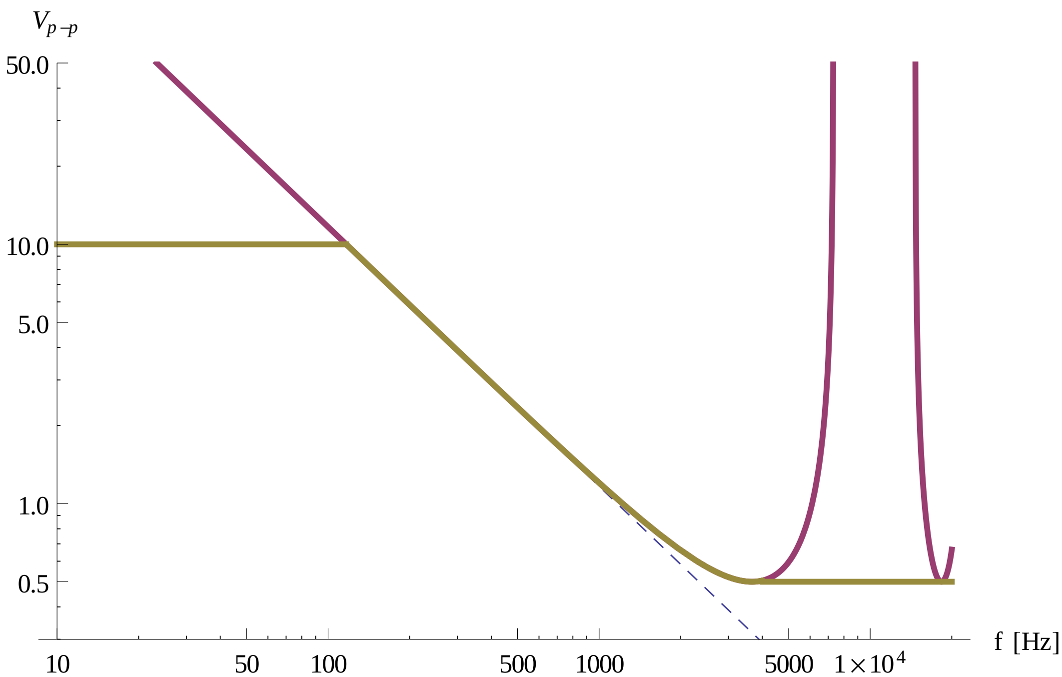
$$V_{\mathrm{p-p}} \sin\left(\frac{\pi f L}{\beta c}\right) < 0.5 \text{ Volt} \tag{2}$$

3 ARIEL case

For worst case, we take the slowest ion as suggested by Friedhelm Ames[2]: ^{238}U at 60 keV[1]so $\beta c = 0.22\,\mathrm{m}/\mu\mathrm{sec}$, $L = 30\,\mathrm{m}$

$$V_{\mathrm{p-p}} \sin\left(\frac{f}{2333\ \mathrm{Hz}}\right) < 0.5\ \mathrm{Volt} \tag{3}$$

This is the area below the solid magenta curve in the following graph.



Note the minimum at 3.7 kHz. The curve swings upward at frequencies beyond this, oscillating between infinity and 0.5 Volt. This is due to resonance effects; we cannot take advantage of this because the frequency is not in our control and we would not be able to lock it. Thus, for $f > 3.7$ kHz, the condition remains at $V_{\mathrm{p-p}} < 0.5$ Volt, as in the brown curve.

For $f < 1.2$ kHz, the condition is $V_{\mathrm{p-p}} f < 1200$ Volt-Hz. This is the dashed line in the plot. For example, at 60 Hz, the allowance is 20 Volts. Realistically, though, this easing does not extend much below 10 Volts, else the power supplies of the electrostatic elements in the beamline will have too much ripple[3].

Overall, I suggest therefore that the peak-to-peak voltage stay below the brown piecewise curve in the figure.

[1] Friedhelm Ames says slowest ion is Uranium at 20 keV. But we do not separate highest mass at lowest energy. Better to use 60 keV; this is where the 1 eV requirement for ΔE comes from.

References

[1] Marco Marchetto, J.A. Maloney, *ARIEL High Resolution Spectrometer Requirements* TRIUMF Document-74319

[2] Friedhelm Ames, informal note (June 2015).

[3] R. Baartman, *Tolerances in the LEBT Optics* TRIUMF Report TRI-DN-97-11.