A NEW CONJOINED RF ION GUIDE WITH INCREASED ION TRANSMISSION FOR LABILE COMPOUNDS

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OVERVIEW

- **Enhanced transmission at intermediate pressures for labile compounds using a novel conjoined RF ion guide.**
- **Studies undertaken on a prototype Xevo TQ-XS tandem quadrupole instrument**
- **Ion transmission increases of up to 50x obtained compared with a standard conjoined ion guide arrangement.**

INTRODUCTION

The use of RF-only ion guides in mass spectrometers is widespread; they are of particular utility in intermediate pressure regions between atmospheric pressure ionisation sources and the higher vacuum analyser chambers. Progress on the efficiency of ion acceptance and transport in such devices at ever increasing operating pressures has been significant over the past 20 to 25 years with designs utilising more traditional multipole ion guides through to various stacked ring electrode designs, and most recently, a conjoined ion guide arrangement [1]. Whilst providing significant transmission increases, the use of such ion guides in pressure regions of > 1mbar can have unwanted effects such as ion heating and therefore fragmentation of labile compounds can readily occur. Presented here is a discussion on the design and performance of a new conjoined ion guide, focusing on increased transmission with particular emphasis on labile compounds through the initial 1 - 10 millibar pressure region in a tandem quadrupole instrument.

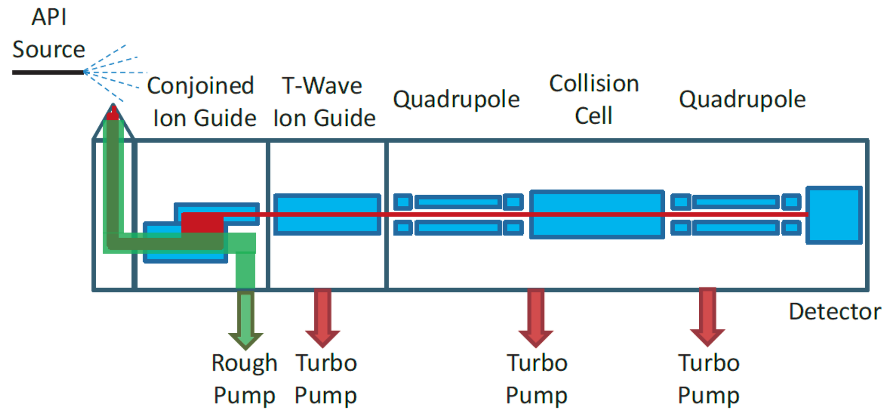

Figure 1 A schematic diagram of the Xevo TQ-S tandem quadrupole mass spectrometer

METHODS

Instrumentation

The instrument used in these studies was a modified Xevo TQ-S instrument (Waters Corp.), shown schematically in **Figure 1**. The conjoined ion guide (StepWave) introduced on the Xevo TQ-S instrument provided significant sensitivity improvements primarily due to it's ability to efficiently capture, confine and transfer large ion currents into the subsequent pressure chamber, whilst minimizing the contamination of the ion optical elements. This process is shown in **Figure 2**.

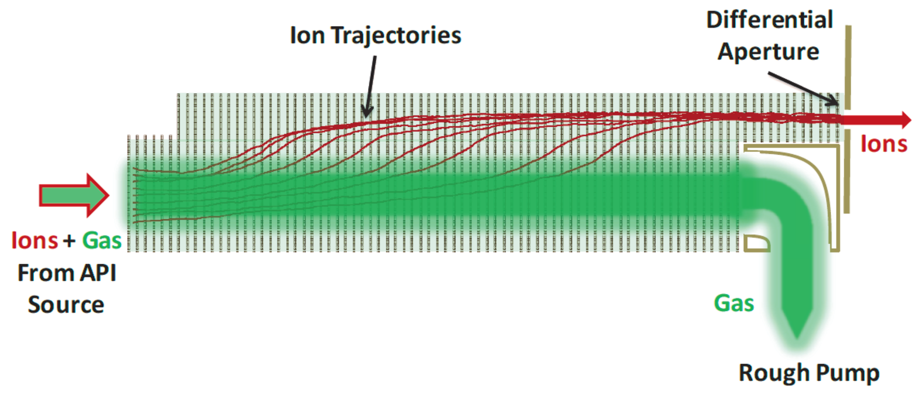

Figure 2 Graphical representation of ion path through a conjoined ion guide design.

The new instrument has novel designs of RF ion guides in the first and second differential pumping regions between the API source and the analyser chamber. This instrument also has a modified pumping arrangement which reduces the pressure in the first differential pumping region. The design of the new conjoined ion guide is shown in **Figure 3**.

As per the original conjoined ion guide (StepWave), first introduced on the Xevo TQ-S instrument, a DC potential is applied to move the ions from the larger ring region into the smaller ring region. However, the original StepWave design relied on DC penetration into the large ring section to extract the entrained ions from the gas flow into the small ring section. In order for all ions to be captured, this method of extraction requires a potential difference of up to 30V to be applied between the ring sections. This can lead to relatively large fields where the large ring section and small ring sections meet. This large field and proximity to RF in this region can impart energy into the ions and lead to fragmentation, particularly of labile species.

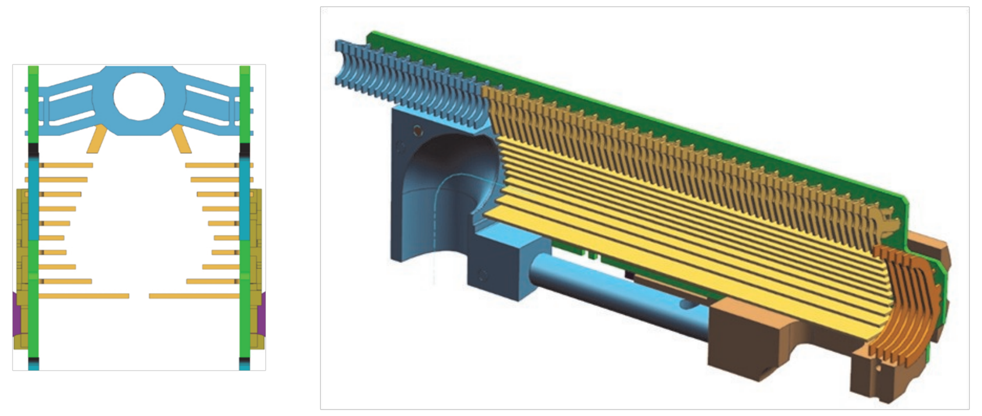

Figure 3 Diagram of the modified conjoined ion guide structure using horizontal plates in the larger ring section.

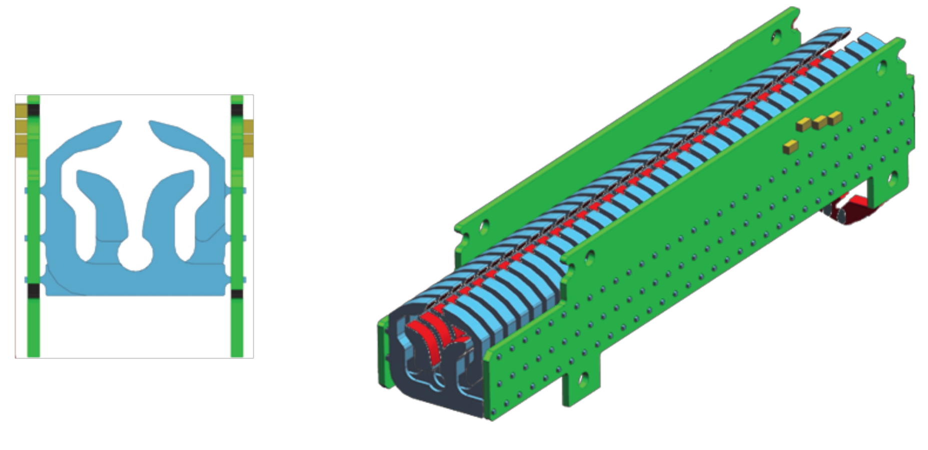

Figure 4 Diagram of the Travelling Wave enabled segmented quadrupole ion guide.

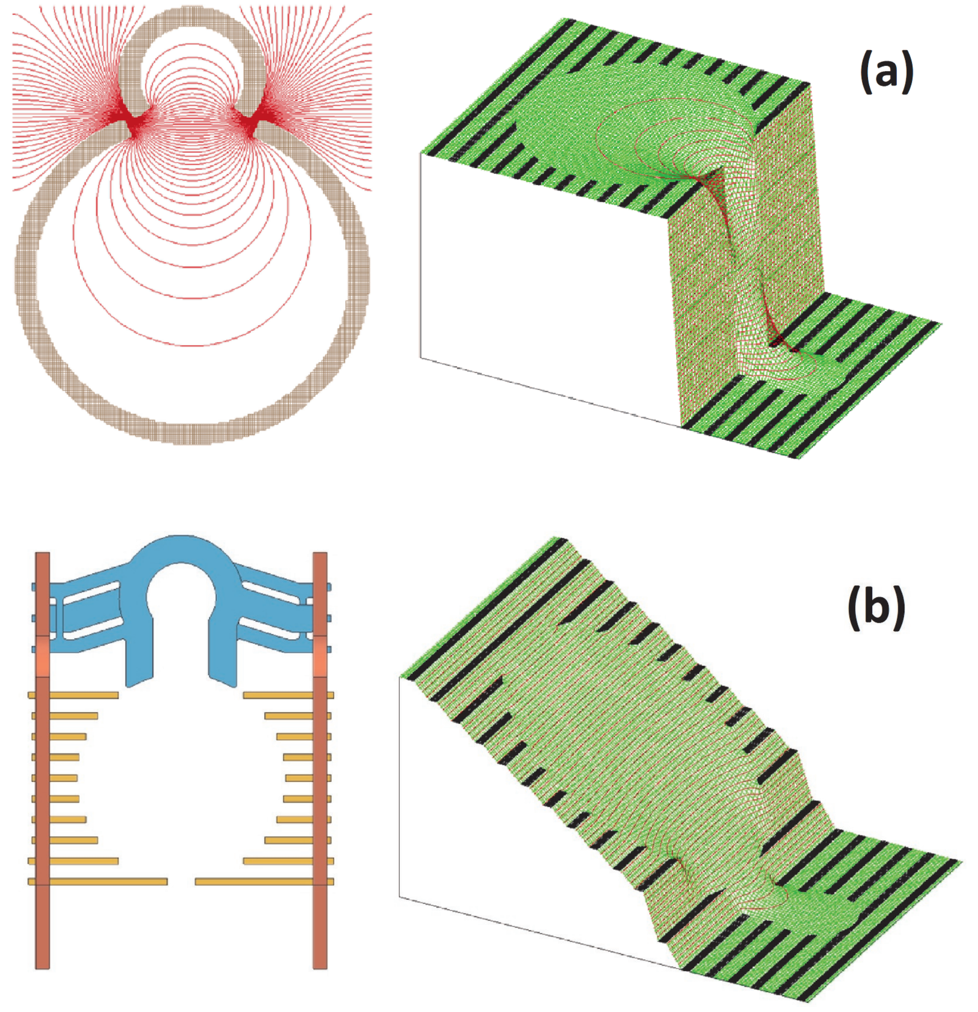

*Figure 5 A simulation comparison between **(a)** arrangement representative of the orignal StepWave and **(b)** the modified StepWave device*

The key physical difference incorporated into the new ion guide design is the use of horizontal plates instead of the large rings. The horizontal plates are arranged to inscribe an area of similar size to the large rings. As with the standard StepWave ion guide, RF is applied the horizontal plates to confine the ions— but the use of horizontal plates allow a DC voltage gradient to be applied between them, allowing full penetration into the large region. This serves two purposes—it allows the use of a smaller potential difference between the conjoined sections and it also removes the large field where the two sections meet. It should also be noted the significant benefit of the off-axis design of the original StepWave device is maintained.

The next stage of the new ion guide is a Travelling Wave enabled segmented quadrupole, located in the second differential pumping region. The design of this ion guide is shown in **Figure 4**. The improved focusing properties of a quadrupole ion guide allow more efficient transport of ions into the analyser chamber and reduce the contamination of the differential pumping apertures, resulting in increased signal and robustness.

Simulations

Initial studies were carried out using the SIMION (v8) ion optics package (SIS Inc.) to identify suitable geometries and potentials to prove the principle of operation.

Various geometries of the conjoined ion guide were assessed, primarily focused on the physical geometry of the region between the horizontal plates and the small ring section. A comparison between the fields present in the standard StepWave device and the new design can be seen in the representation shown **Figure 5.**

RESULTS AND DISCUSSION

Transmission Characteristics

A prototype Xevo TQ-XS instrument was then constructed incorporating both new ion guides.

Figure 6 shows the transmission of a range of m/z as function of the RF amplitude applied to the modified conjoined ion guide. For fast mass switching experiments with low dwell times, it was found operating the ion guide at a fixed RF was beneficial in maintaining sensitivity. The RF applied to the conjoined ion guide is therefore fixed at 150V pk-pk. The option is available to use an RF amplitude of 50V pk-pk with a reduced voltage across the horizontal plates. As **Figure 6** suggests, this lower voltage mode is beneficial for low mass compounds but can also lead to significant additional improvement in transmission of labile compounds.

Figure 7 shows the preliminary data obtained using a modified Xevo TQ-S instrument containing the first ion guide design shown in **Figure 3**.

Gains in transmission of over 50x were obtained on some labile compounds with this geometry.

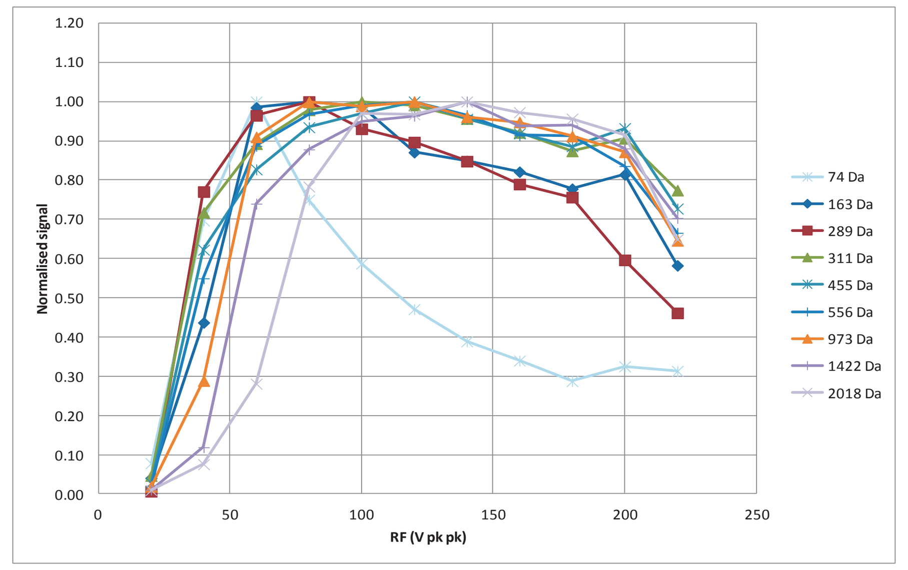

Figure 6 Transmission properties of the new conjoined ion guide as a function of RF amplitude at 1MHz in a pressure in the region of 2 mbar.

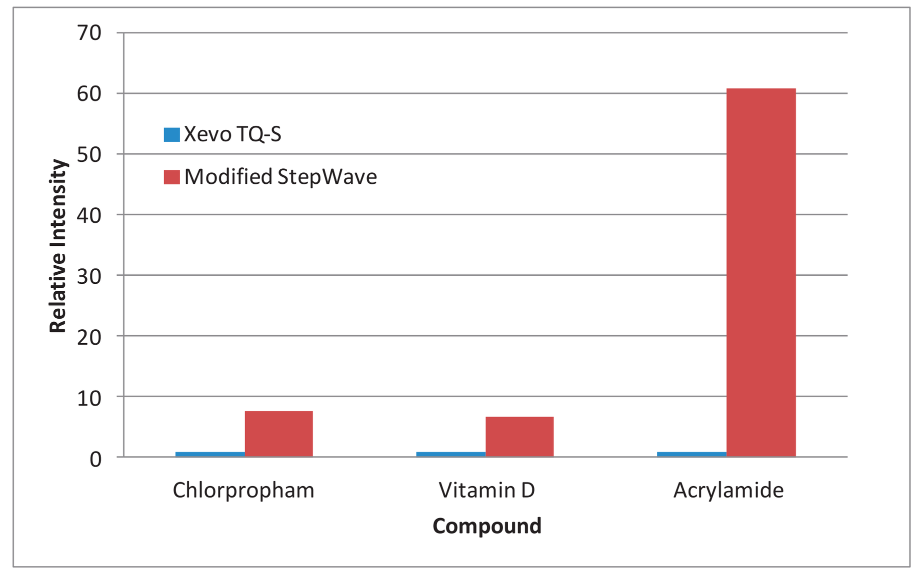

Figure 7 Initial UPLC/MRM data showing signal comparison between the standard StepWave device and the new Stepwave XS device.

System Performance

To evaluate the overall performance for the prototype Xevo TQ -XS, several experiments were preformed and the results compared with the Xevo TQ-S instrument.

Figure 8 shows the results of a UPLC/MRM acquisition of 50fg on-column injections of Aldosterone where a signal to noise increase of approximately 5x was observed with the new ion guide design. **Figure 10** highlights the performance gains using the new ion guide system for a range of compounds compared to the standard Xevo TQ-S instrument. As can be seen, significant benefits were obtained, particularly for the more labile compounds.

Since the off-axis design of the original StepWave is maintained, which reduces the physical deposition of material on the critical ion optic elements. **Figure 9** highlights the robustness of the new ion guide with < 3% RSD variation in peak area from >2000 injections of Sulphadimethoxine in protein-precipitated plasma (100 fg on column) - even when mass switching with no internal standard and 5ms dwell times.

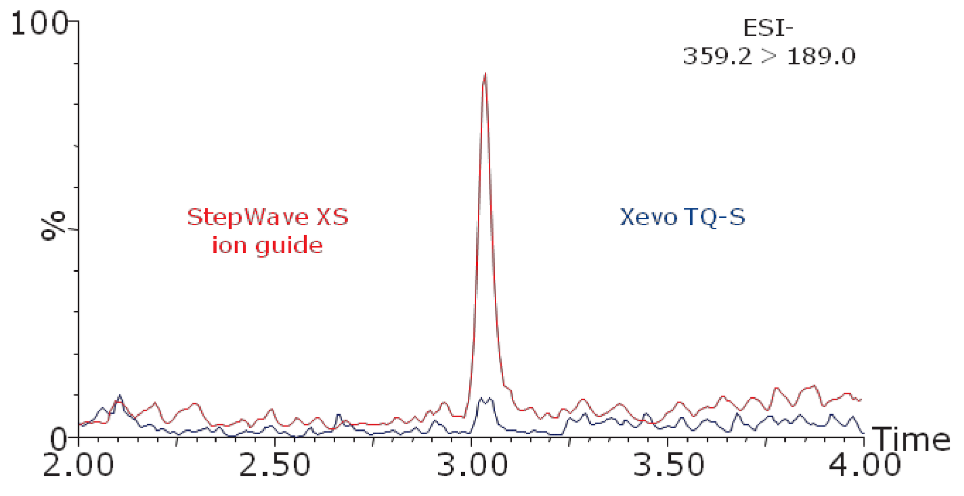

Figure 8 UPLC/MRM acquisition of Aldosterone comparing the signal on the Xevo TQ-S to the Xevo TQ-XS .

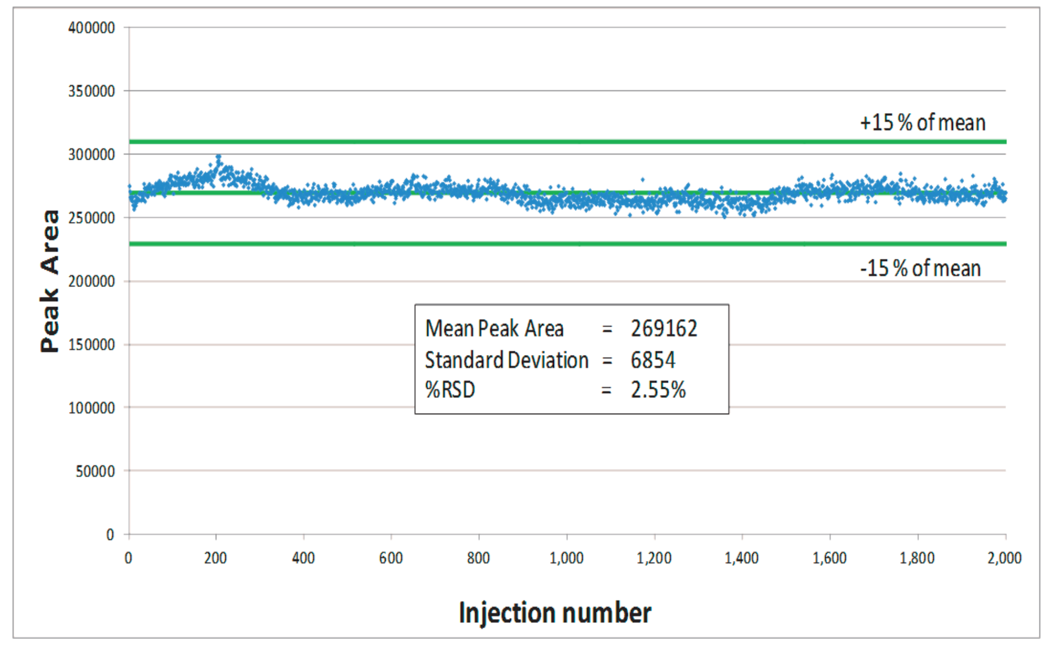

Figure 9 Replicate injections of Sulfadimethoxine spiked into protein precipitated plasma, mass switching at 5ms dwell time with no internal standard.

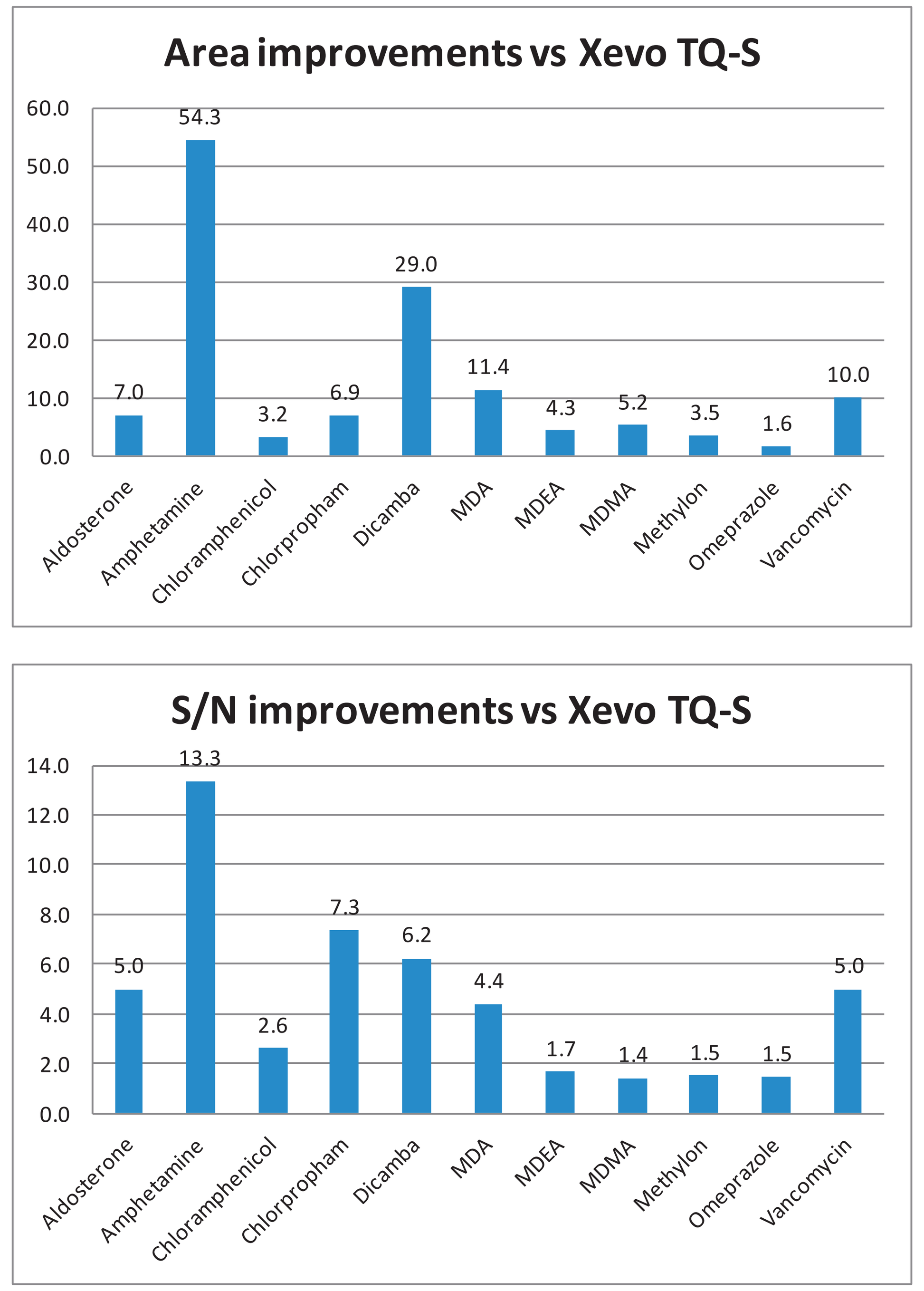

Figure 10 UPLC/MRM acquisition results for various compounds in ESI+ and ESI– mode highlighting the Area (top) and S:N (bottom) difference between the Xevo TQ-XS and Xevo TQ-S.

CONCLUSION

- **A novel conjoined ion guide design coupled to a segmented quadrupole ion guide**
- **Transmission improvements on all compounds measured, up to 50X for labile/fragile compounds.**
- **Maintains off-axis design from the original StepWave device providing robust performance.**

Acknowledgement

James Morphet, Jonathan Fox and Robert Lee (Waters, Manchester) are thanked for providing the system performance data in this presentation.

References

1. K Giles, A New Conjoined RF ion Guide for Enhanced Ion Transmission, Poster ASMS Conference 2010

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