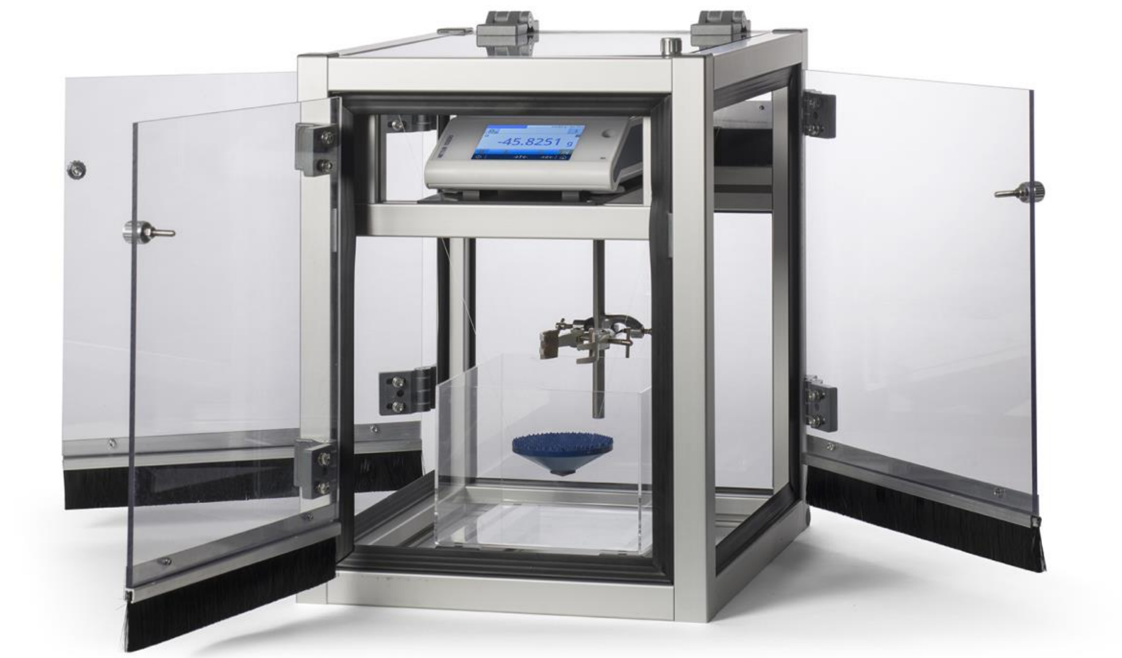
PRECISION ACOUSTICS

Radiation Force Balance



The Radiation Force Balance (RFB) is a device for the rapid and accurate measurement of ultrasonic power. Precision Acoustics Ltd have designed this equipment for use in the frequency range 1 MHz to 20 MHz. It is capable of measuring powers from 20 mW to 100 W.

The IEC standard 61161 [3] is applicable above 500 kHz and the Radiation Force Balance complies with this standard.

For ultrasonic power measurement below 500 kHz, Precision Acoustics Ltd also offers a lower frequency RFB optimised for frequencies in the range 200 kHz to 1 MHz.

Precision Acoustics Ltd, Hampton Farm Business Park, Higher Bockhampton, Dorchester, Dorset DT2 8QH, UK
t. +44 (0)1305 264669 f. +44 (0)1305 260866 e. pa@acoustics.co.uk w. acoustics.co.uk

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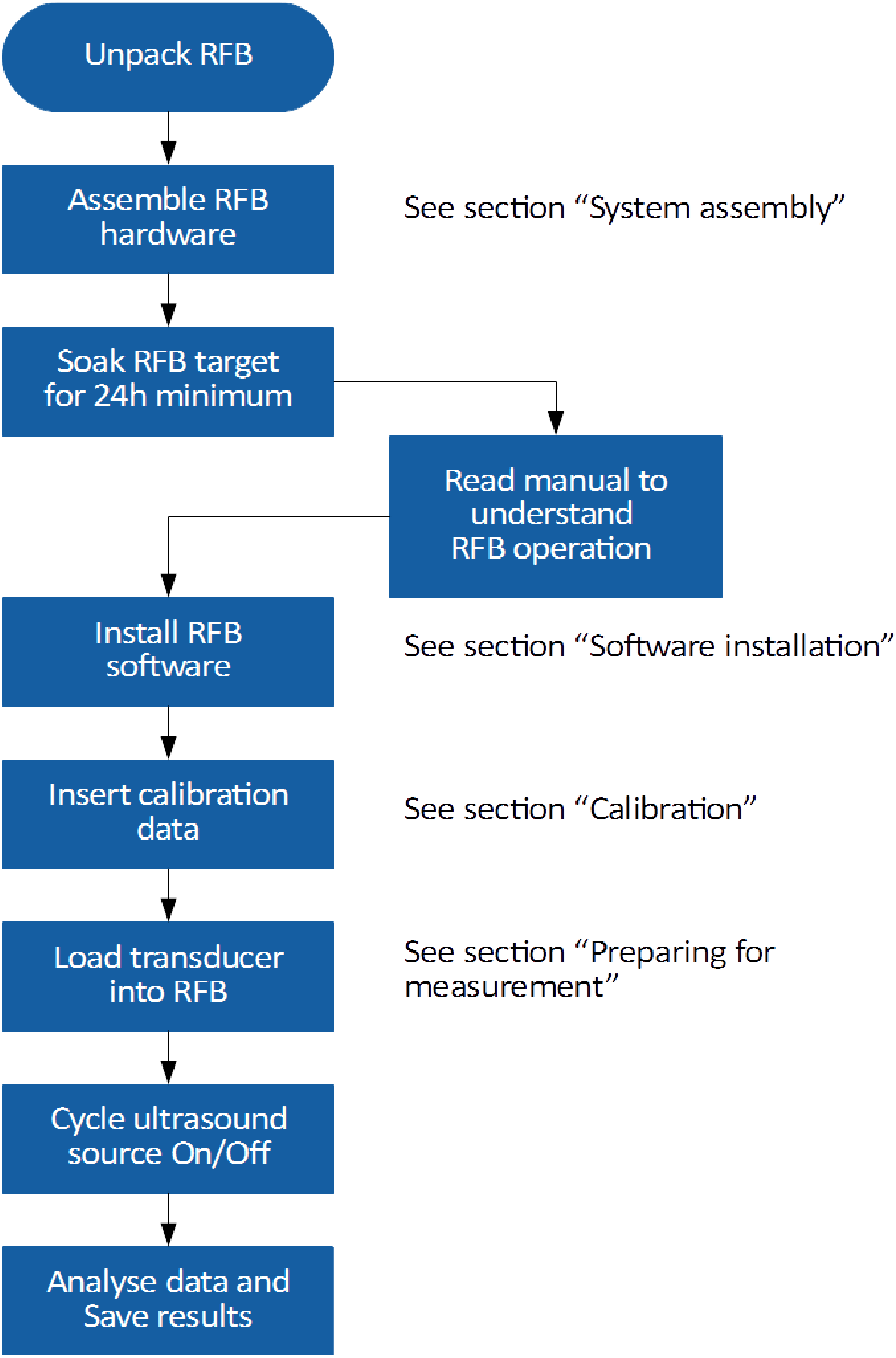
VERSION HISTORY

Version	Date	Change
4.13	11/02/2021	Added version history, table of contents/figures and moved software installation section nearer start of document
4.14	16/09/2021	Updated for v2.1 of software. Updated balance selection and configuration,
4.15	23/05/2023	Brand changes

QUICK START FLOW CHART



INTRODUCTION

This document describes the use of a Radiation Force Balance (RFB) to determine total ultrasonic power radiated in the forward direction from transducers operating in the frequency range 1 MHz to 20 MHz. The mass change reported by the balance is output, via a serial interface, to a host PC for subsequent analysis. RFBs have been calibrated by NPL at a wide range of powers and frequencies; contact the team at Precision Acoustics Ltd for calibration options. Additional information on making ultrasonic power measurements can be found on our website (http://www.acoustics.co.uk). In addition, Precision Acoustics Ltd offers training courses covering many aspects of acoustic measurement techniques and practices.

Unpacking the hydrophone system

Each Radiation Force Balance system contains several components. Carefully remove the packaging and identify the following parts. If any item is missing or damaged, then please contact Precision Acoustics Ltd.

(1) Analytical balance and instruction manual

(2) RFB instruction manual

(3) Software installation CD

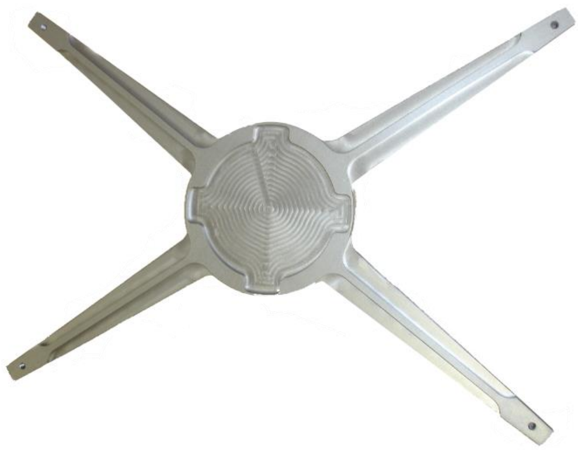
(4) USB-A to USB-B communication cable

(5) Retort stand and transducer clamp

(6) Draught shield

(7) Plastic gantry adapter

(8) Target support gantry (metal cross)



(9) Calibration certificate (printed)

(10) Absorbing ultrasound target

(11) Water vessel

See Figure 1 for details

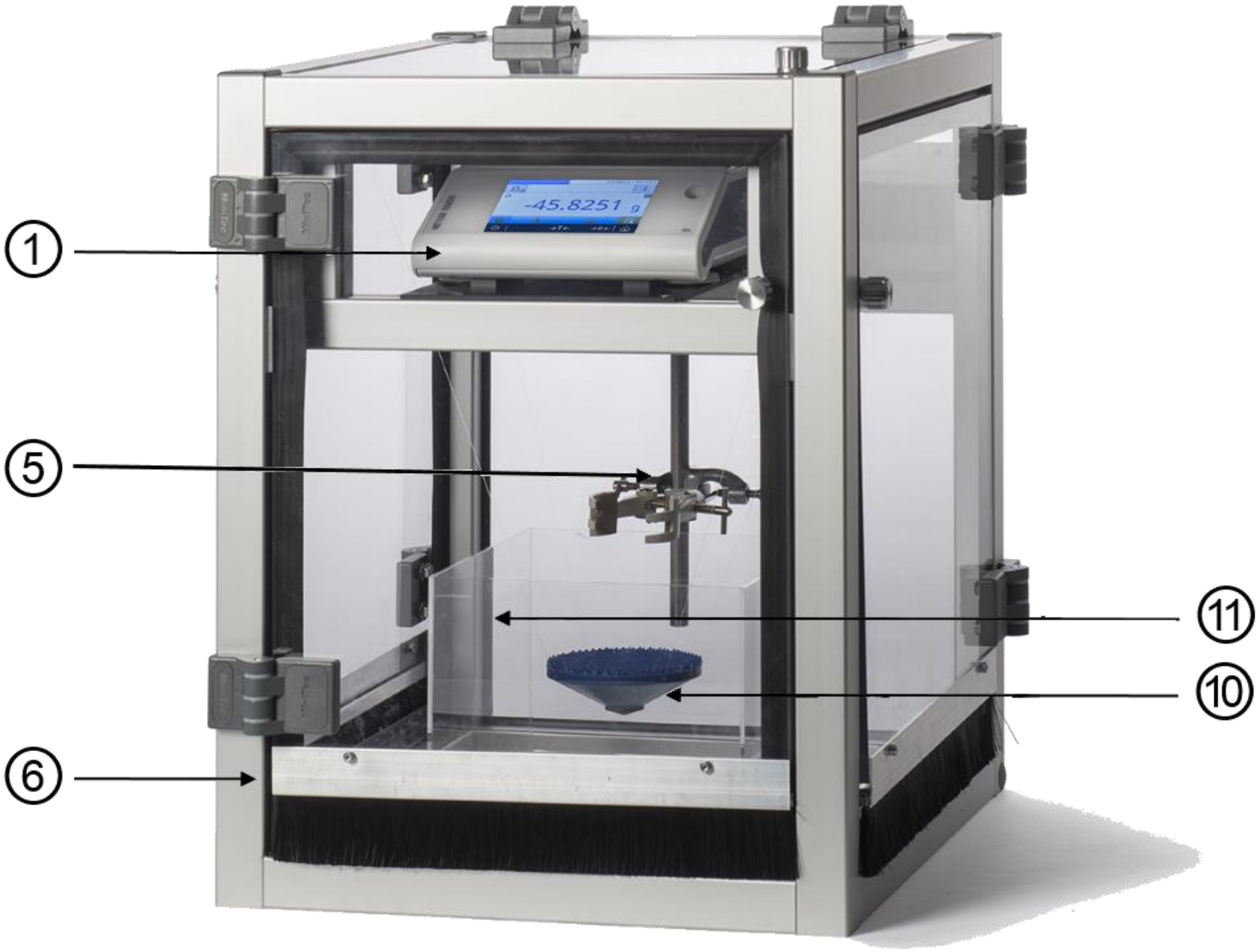


Figure 1– RFB assembly. see Unpacking the hydrophone system for numbered parts.

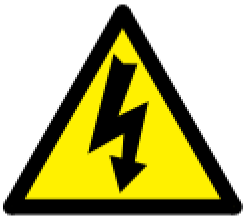
SPECIFICATIONS

Parameter	Value	
Frequency range	1 MHz to 20 MHz	
Power range	20 mW to 100 W	
Calibrated dynamic range	See calibration certificate	
Total measurement uncertainty	>50 mW	± 7 % (95 % confidence)
	<50 mW	± 10 % (95 % confidence)
Target diameter	100 mm	
Maximum transducer diameter	Approximately 70 % of the target diameter	
Echo reduction of target	Suspended Target: > 43 dB	
Insertion loss of target	30 dB cm^{-1} MHz^{-1}	

Table 1 – RFB specifications

The RFB may be used outside of these ranges with increased uncertainty levels.

IMPORTANT NOTES



The RFB is mains operated and should be connected to the mains supply via a Residual Current Device (RCD).

WARNING: Ensure that the focus of the acoustic field (especially for a strongly focussed transducer) does not lie within the absorber, since high intensities can cause irreversible damage to the absorber.

SYSTEM ASSEMBLY

Before assembling the system please consult the Environmental conditions section of this document. RFBs are very sensitive to vibration and air currents and choice of location for the RFB should be considered with care

1) Place the water vessel on a stable surface and place draught shield over the water vessel.
2) Place the balance on the top plate within the draught shield and connect the power supply and USB cables to the rear of the balance. These cables should exit the draught shield at the rear.
3) Fit the plastic gantry adapter into the 4-arm target support gantry and then fit the gantry assembly onto the top of the balance.
4) Located the absorbing target and spread the support wires out evenly.
5) Place the absorbing target in the empty water tank underneath the balance.
6) Drop the threaded connector on the end of the support wires into the target support gantry; ensure the target is fully suspended beneath from the support gantry.
7) Adjust the locating screws to ensure that the suspended target is level and that all support wires have approximately equal tension.
8) Fill the water vessel with deionized/degassed water (see section on Water quality (below) for more details).
9) Adjust level of balance using the rotating feet and bubble level.
10) Leave the target in water for at least 24 hours before measurement.

SOFTWARE INSTALLATION

1) Insert the “Radiation Force Balance” Software Installation CD.
2) Run “\RFB installer\setup.exe” to install the main RFB computer application.
3) Run “\Mettler-Toledo USBDriverInstaller.exe” to extract the USB adapter driver files and then run “setup.exe”.
4) Connect the balance to the PC, using any available *USB* port.

Initial configuration

1) Run the “RFB 2” program.
2) On first run, configure the balance by completing the information in the window that pops up (see Figure 2).

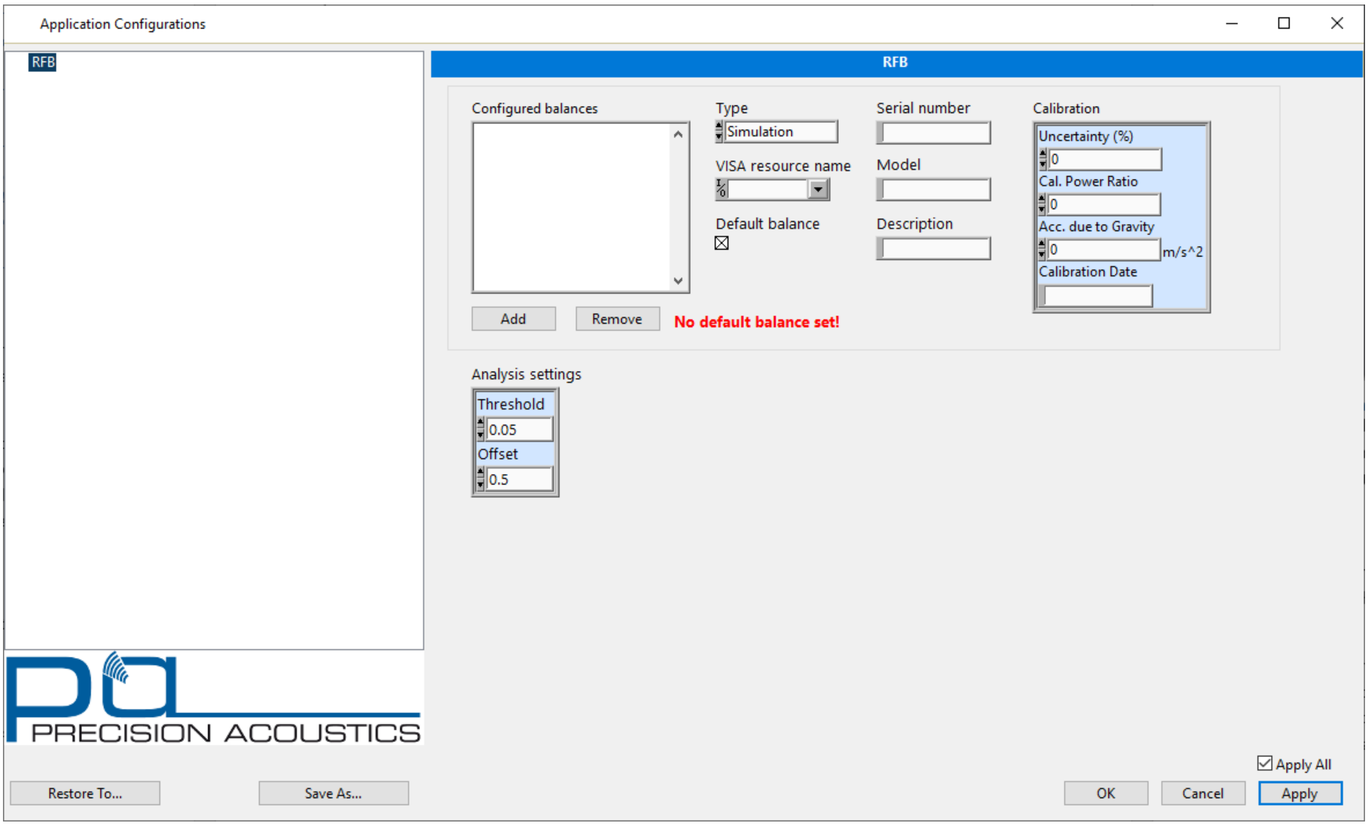


Figure 2 – Balance configuration dialog

3) Click “Add” to create a new balance configuration
4) Select the balance “Type” from the drop down list
5) Select the COM port associated with the balance
6) Enter the balance Serial number, Model and a Description (Note these fields are for information and record keeping only
7) Enter the calibration data from the calibration certificate supplied with the system.
    a. If the RFB is supplied uncalibrated then use the value of 1.0 in the “Cal. Power Ratio” control
8) Click “OK” to apply and save the settings and proceed to the main application.

9) In the main application interface, press the **START** button and confirm that the PC is communicating correctly with the balance. If, after a few seconds, the data display starts to update, the RFB is correctly set up.

SUBSEQUENT STARTS – SELECTING A BALANCE

The "**Select Balance …**" dialog box (see Figure 3) is displayed every time the RFB2 application is run and allows the user to specify a balance configuration to use for this instance of the application.

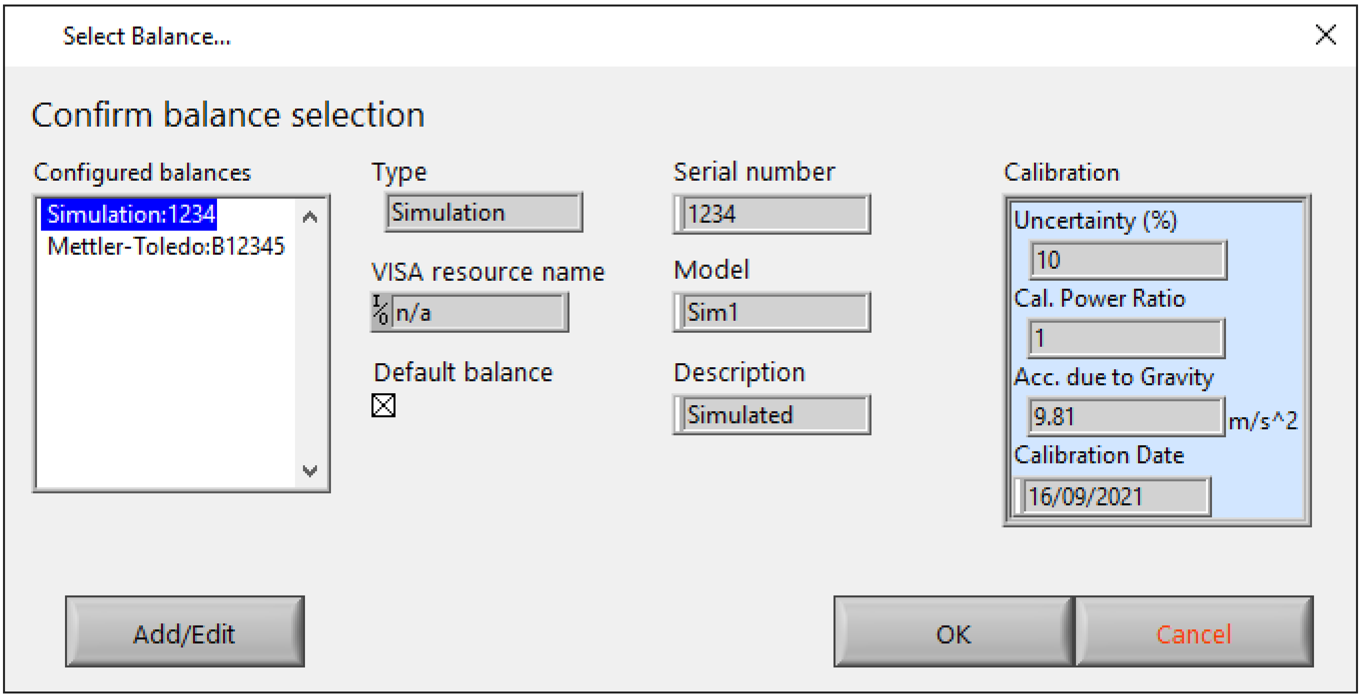


Figure 3 - Select balance configuration dialog

Using a pre-configured balance

1) Select a balance from the **Configured balances** list to choose the required device configuration. The details of that configuration are shown in the dialog
2) To accept these details, press the OK button or return to step 1)

To create a new balance configuration

1) Click Add/Edit button to open the dialog shown Figure 2
2) Repeat the process given in the "initial configuration" step to add a new balance

UPDATING THE SYSTEM SETTINGS

Click on the **Settings** menu and then **Balance Settings** to display the configuration dialog (see Figure 2). From here it is possible to change the configuration of an existing balance (E.g. update the calibration data, or change the assigned COM port etc) or add a new balance.

Analysis settings

These are the default settings for the parameters used in the automatic analysis of RFB data. These default values can be altered on a measurement-by-measurement basis. See the section Automatic analysis process for a detailed discussion of each parameter.

New settings are applied by clicking Apply or OK.

If settings are changed it is necessary to restart the software to ensure they are properly applied.

PRINCIPLES OF OPERATION

Overview

Radiation force occurs whenever an ultrasonic wave is incident upon a target material. The wave transfers momentum to the target and this produces a net force. The target is attached to an accurate analytical balance and thus the force is registered by the balance as a change in mass. The total mass measured by the balance, m_{total}, is given by

$$m_{total} = m_{target} + m_{rad}$$

Where m_{target} is the apparent mass of the target and m_{rad} is the mass corresponding to the vertical component of radiation force. For a perfectly absorbing target, the acoustic power derived by RFB, P_{RFB}, can be found by using the equation

$$P_{RFB} = c(T).m_{rad}.g.F_{CAL}.F_{IEC\_Corr}$$

Within Table 6 the following variables are used:

c(T) = temperature dependent speed of sound in pure water at temperature (*T*)

g = acceleration due to gravity

F_{CAL} = Calibration correction factor

F_{IEC_Corr} = Correction factors to account for non-ideal behaviour as specified in IEC 61161 [1] (see section Correction for non-ideal fields)

the temperature dependence of the speed of sound in pure water is well established [2] and the polynomial description of this dependency is included within the RFB software. For convenience, a few values for *c(T)* in the region of 20 °C are listed in Table 2.

Temperature (°C)	Speed of sound (ms^{-1})
18	1476.05
19	1479.25
20	1482.36
21	1485.39
22	1488.34
23	1491.20

Table 2 - Temperature-dependence of speed of sound in pure water

Using the speed of sound at 20 °C from Table 2 and assuming g = 9.81 ms^{-2}, leads to the following approximation

$$P_{RFB} \cong m_{rad}.14.5\ mW\ mg^{-1}.$$

However local values of g may vary, and the correct value should be input to the dialog shown in Figure 3. Similarly, the correct value for the water temperature should be entered into the front panel of the RFB software each time a measurement is made.

Experimental practicalities

Note that m_{target} is not constant; it may vary during the course of the measurement. This is because ultrasonic energy absorbed by the target is converted to heat which in turn causes thermal expansion of the target material. This expansion changes the targets density and thus its buoyancy in water. Consequently, the apparent mass of the target may change as it heats and then cools during the course of a measurement. This is particularly noticeable at high powers where the ultrasonically induced heating may be several °C. Accurate power measurement is thus only possible if the component of mass due to radiation force, m_{rad}, can be isolated from the total mass, m_{total}.

These effects are clearly evident in Figure 4 where a ≈3W ultrasonic transducer has been placed in an RFB and then switched on for 4 separate bursts of approximately 15 seconds duration. For convenience, the points at which the transducer has been switched on (on-going transitions) have been marked with a black arrow. Similarly, the points at which the transducer ceases to output ultrasound (off-going transitions) have been marked with an orange arrow. The upward drift between the on- and off-going transitions is as a result of buoyancy changes in the target as ultrasonic energy is absorbed.

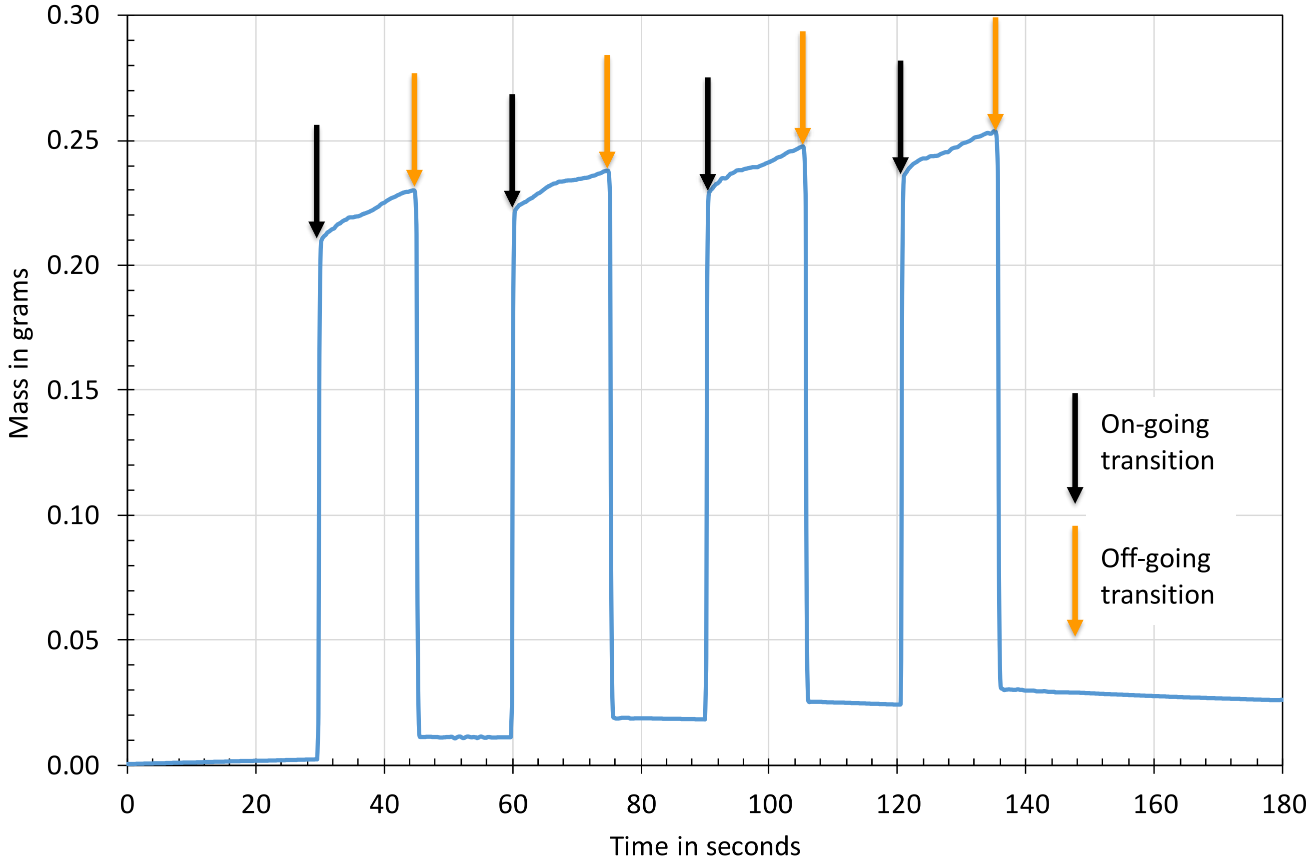


Figure 4 - Typical RFB measurement trace

Note that although there is a lot of variation in total mass, the magnitude of change in mass at the transition points is much more consistent and therefore provides a more accurate value for m_{rad}. Figure 4 also shows that there is some variation from one off-on-off cycle to the next. Single measurements are often prone to error and thus off-on-off cycles (as shown in Figure 4) should be used to reduce experimental uncertainty.

Automatic analysis process

The RFB software provides the facility to automatically determine the transition point from an RFB measurement trace. Please note that not all RFB data has such readily identifiable transitions as are shown in Figure 4. At low powers (<100 mW), noise may be evident on the trace, and some transducers exhibit considerable output instability immediately after they are switched on. In these cases, it may not be possible to use the automatic analysis. If this is the case, transition points need to be manually determined; the manner this is achieved within the software is discussed in section entitled <u>Manual determination of transition point</u>.

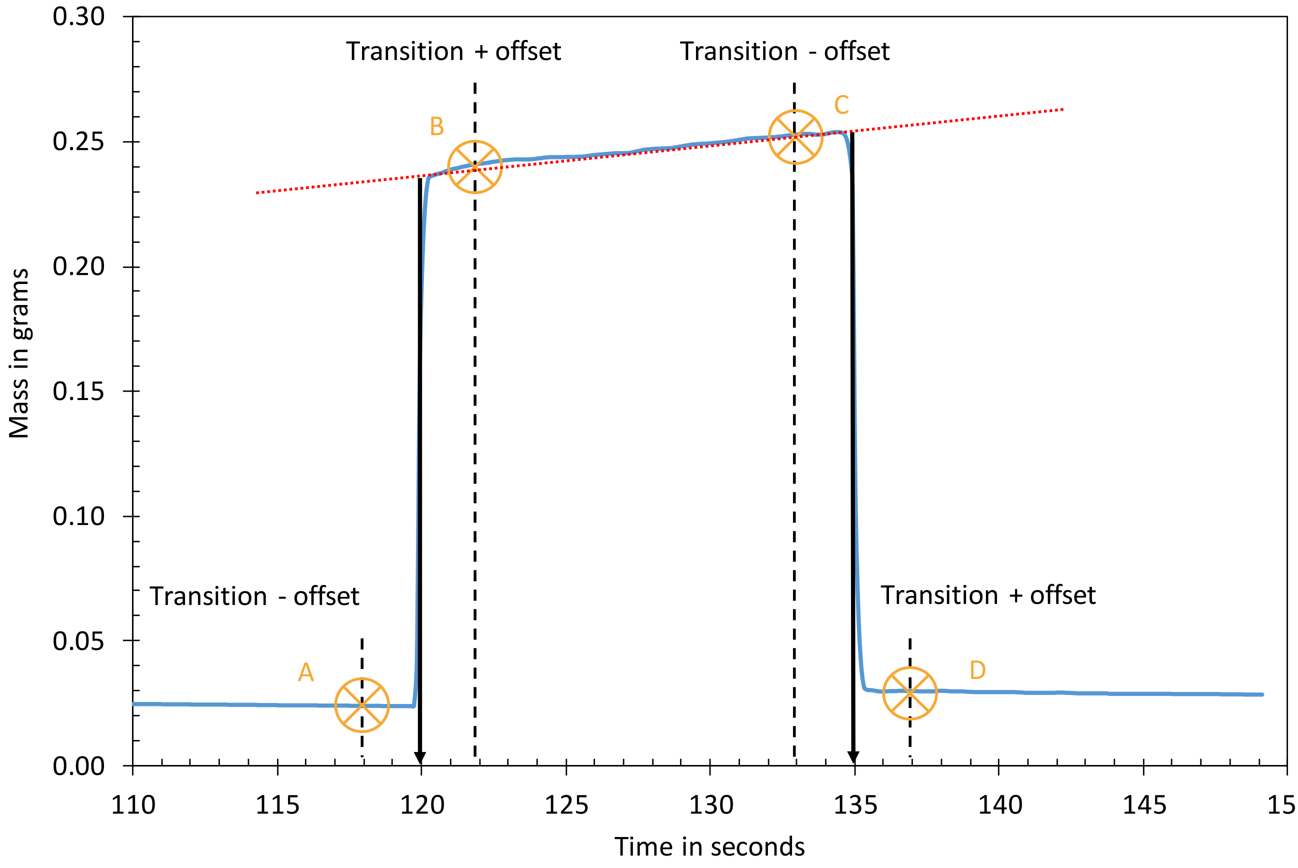


Figure 5 - Transition points and offsets

The automatic analysis begins by calculating the derivative with respect to time of the mass trace. The on-going and off-going transition points are determined from the location at which the gradient of these curves take their maximum and minimum values. These points are identified on Figure 5 with a solid black arrow. Within the RFB software there is a **Threshold** control value that alters the sensitivity to changes in the gradient of the mass trace. Reducing the value of the **Threshold** control, increases sensitivity.

The next stage in the analysis is to determine representative mass values either side of the transition. To avoid discrepancies introduced by output instability immediately following a transition, an offset time is applied to the time of transition. Dashed lines on Figure 5 mark the (Transition – offset) and

(Transition + offset) times and the mass is determined from these times. These are identified on Figure 5 with an orange circle and cross and are labelled A, B, C and D. Within the RFB software there is an **Offset** control to enable the user to adjust this as required.

Theoretically, m_{rad} could be determined from the difference of mass values at each transition – in this case (B – A) and (C – D), but this method is very sensitive to the transient response of the signal source during power on. Therefore, a least-squares method is used to fit a straight line (shown in red dots within Figure 5) to the two upper points (B and C). Similar baseline fitting is conducted for the lower points (A and D). The values of the resulting least-squares lines are then used to calculate the mass due to radiation force, m_{rad}, at the two transition points.

Correction for non-ideal fields

Three corrections can optionally be applied, using methods described in IEC 61161 [1]. For each correction, the ratio of the corrected/uncorrected power value is displayed. These corrections can be separately applied or in combination. The correction is only applied if the displayed value is enabled. All three physical phenomena act to reduce the radiation force at the target, so the corrections will always be positive.

Cause of correction	IEC61161 Clause	Correction applied
Absorption of energy in the propagation fluid	B.3.2	$P_{Corr} = P_{Uncorr} e^{2\alpha f^2 z}$
Non-normal incidence of energy in focussing fields	B.5	$P_{Corr} = P_{Uncorr} \left(\frac{2}{1 + \sqrt{1 - \frac{a^2}{d^2}}} \right)$
Departure from ideal plane waves due to transducer size	E.1	$P_{Corr} = P_{Uncorr} \left(\frac{1 - \frac{J_1(2ka)}{ka}}{1 - {J_0}^2(ka) - {J_1}^2(ka)} \right)$

Table 3 – Correction factors specified in IEC 61161

Within Table 3 the following variables are used:

P_{Corr} = Corrected power

P_{Uncorr} = Uncorrected power

α = 2.3x10^{-4} MHz^{-2} cm^{-1},

f = frequency in MHz

z = transducer-target distance in cm

k = angular wave number

a = transducer element radius

d = geometric focus (radius of curvature)

CALIBRATION

NPL calibration values typically take the form of a table of $\left(\frac{\text{Measured power}}{\text{Applied power}}\right)$ at a range of frequencies and powers; example data can be found in Table 4.

Frequency (MHz)	Applied power (mW)	Ratio $\left(\frac{\text{Measured power}}{\text{Applied power}}\right)$
1.0	20	1.00 ± 18 %
	200	0.97 ± 6 %
	500	0.97 ± 6 %
2.25	20	0.98 ± 17 %
	200	0.97 ± 6 %
	500	0.97 ± 6 %
3.5	20	0.99 ± 19 %
	100	0.98 ± 10 %
5.0	20	1.00 ± 18 %
	100	0.97 ± 10 %

Table 4 – Example calibration data

The vast majority of calibration ratios lie within the range 0.96 to 1.00. Many users therefore find it convenient to use a single calibration factor derived from the mean of the calibration factors on the certificate. Although this may introduce an additional uncertainty, this is typically <2% and thus negligible when compared to the overall uncertainty in the measurement. For the case of the data in Table 4, using a single calibration power ratio of 0.98 is likely to introduce a negligible measurement uncertainty.

Each ratio has its own associated uncertainty; note that measurements at lower powers, and higher frequencies tend to have higher uncertainties. If it is anticipated that there will be many measurements made under such conditions, then see the section **Error! Reference source not found.** to create an additional balance configuration. In this case use an amended serial number (e.g. 12345-LOW POWER) along with the calibration power ratio and uncertainty for that measurement condition.

Calibration data comprising T, Uncertainty (UC), power ratio and g can be entered via the balance selection screen when the software is started up. Simply enter the data in the relevant fields and click "OK". These values are taken from the calibration certificate and are saved to a configuration file and can be restored on subsequent use by selecting the balance (identified by its serial number) from the drop-down selector in the balance selection dialogue. To change balance, it is necessary to exit and restart the software.

PREPARING FOR MEASUREMENT

Prior to measurement, switch on the PC and once Windows has loaded, turn on the balance. For the most accurate measurements, allow at least 1 hour for the equipment to warm up and stabilise. It is important to ensure all bubbles are dislodged from the target, using a small paintbrush if required.

The target should be allowed to soak for at least 24 hours to allow water absorption to stabilise, air at the surface to dissolve and bubbles to dissipate.

If any bubbles remain on the front face of the transducer, ensure that these are wiped away/dislodged. Immersing the transducer with the face at an oblique angle can help minimise bubble entrapment. Once immersed fully, the transducer should be aligned so that its acoustic axis points vertically downwards.

Hold the transducer to be measured in the clamp provided (⑤ in Figure 1) so that its front face is fully immersed and positioned centrally above the absorber. When measuring strongly focussed fields, the target of the RFB should be well within the pre- or post-focal regions (Figure 6 and Figure 7 respectively) as high intensity fields have the potential to damage the absorber.

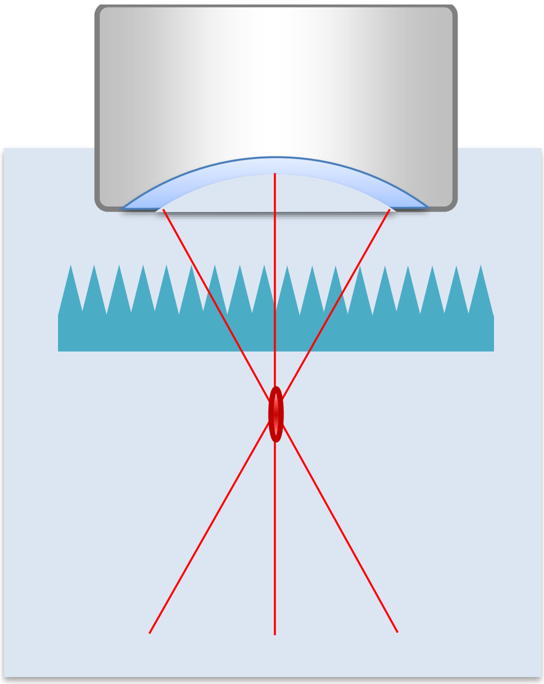


Figure 6 – RFB target in the pre-focal region

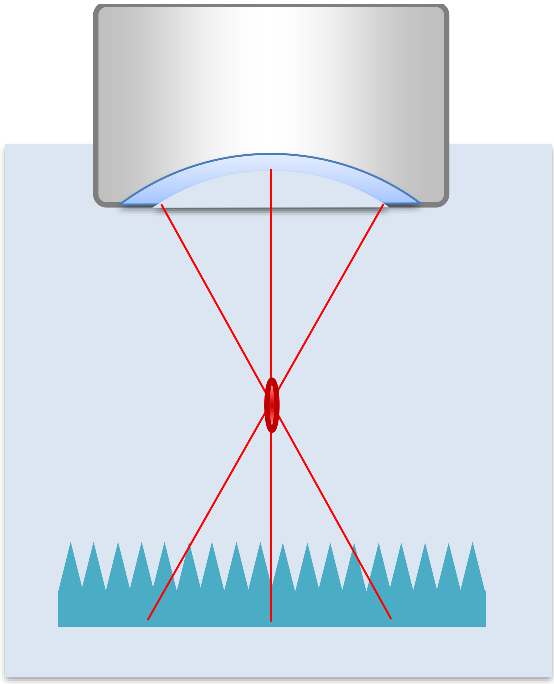


Figure 7 – RFB target in the post-focal region

When the RFB target is in the post-focal region (Figure 7) there is the chance that the RFB target will not encompass all of diverging beam. Therefore, of these two configurations, placing the transducer such that the RFB target is pre-focal is preferred. A distance between the transducer and absorber should ideally be about 10 mm. Once the transducer alignment process is complete, tare the balance so that the reading is near zero.

Divergent beams

It should also be remembered that the forward ultrasound power (i.e. the component which is travelling vertically downwards) is always smaller than the total radiated power. For many transducers the difference will be perhaps 2% or less, which is much smaller than the declared uncertainty. However, for very strongly divergent transducers, strongly focused transducers or transducers which radiate in a sector format (for example, curvilinear or phased array imaging transducers) the difference could be much larger. There is also the risk that the target will not be large enough to encompass all of the radiated acoustic field from a strongly divergent transducer; minimising source-target distance is recommended.

MEASUREMENT PROCEDURE

1. Run the “RFB 2” program and select the RFB configuration from the dialog box (Figure 3).
2. The main RFB window will be displayed (Figure 8).

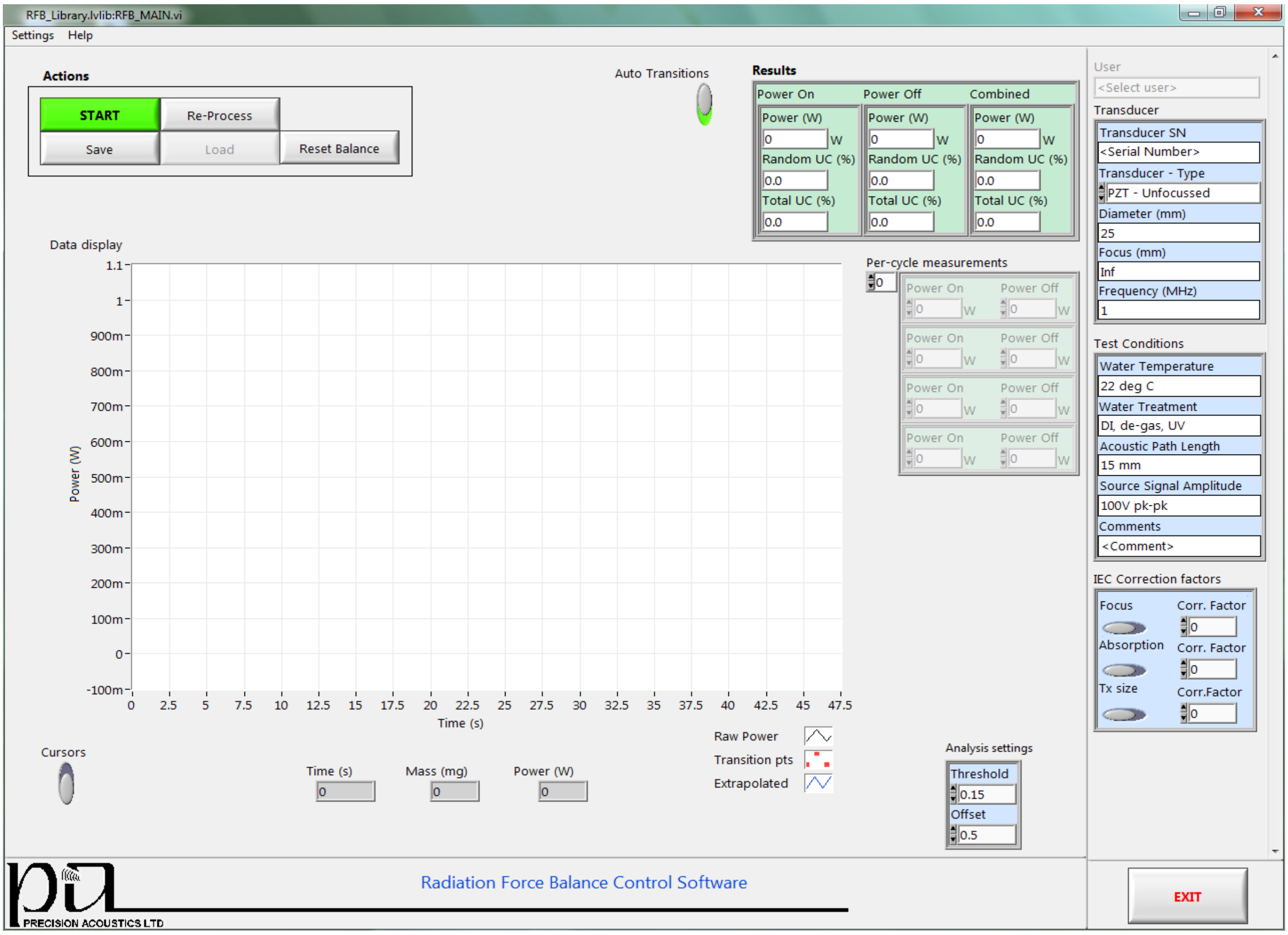


Figure 8 – RFB software main window

3. Ensure that the correct value for water temperature is installed in the **Test conditions** box on the right-hand side of the screen.
4. Press the **START** button and allow the system to acquire data for at least 10 seconds with no acoustic signal input. This is to establish a baseline.
5. Turn the signal source on and off, using the time intervals in Table 5 as a guideline.

	Low output (<1 W)	Mid output (1-5 W)	High output (>5 W)
ON time	20 s	10 s	6 s

Care should be taken when operating a transducer at higher acoustic power levels (>5 W). The absorbing material is susceptible to damage when exposed to higher levels of acoustic power for prolonged periods. As a guide, for power measurements above 10W, the duration of the OFF time should be at least ten times the ON time.

Table 5 – Recommendations for exposure times at different power levels.

6. The display graph will be updated with live data and will be continuously updated until the acquisition is stopped. The graph contains three traces:
   - Raw Data – mass readings from the balance converted to power, using the calibration information

- Transition Points – marking start and stop of positive and negative power transitions
- Extrapolated Data – linear least-squares fit to the raw data between the upper transition points, extrapolated to the lower transition points.

7. The program will monitor the input signal and automatically detect off-on and on-off transitions.
8. Each time a valid power cycle (off-on-off) has been detected, the acoustic power is calculated for both transitions and entered into the **Per-cycle measurements** table. This will display the first four measurement cycles – scroll down to see more than four.
9. Calculated power values are also entered into the **Results** table, which provides a basic statistical analysis facility. The statistics will be updated as more measurements are added.
10. The automatic analysis algorithm offers interactive control of two threshold values from the front panel. These thresholds can be adjusted during live data acquisition, so that changes can be immediately assessed. However, note that this adjustment will cause ALL THE DATA to be re-analysed
    - **Threshold** controls the amplitude at which a transition is detected – increasing the value reduces the sensitivity of the algorithm.
    - **Offset** controls the time shift between the detected peak and the true position of the transition points – increasing the value pushes the transition points away from the rising/falling edge of the raw data trace.
    - If noisy, or low power data makes automatic determination impractical see the section Manual determination of transition points.
    - Press **STOP** to finish the measurement.
    - Data can be only be re-processed and/or saved to file when not in live acquisition mode.
    - Press **EXIT** button to terminate program.

Manual determination of transition points

1. Automatic analysis of transitions cannot take place while the RFB is acquiring live data. Therefore, ensure that the **STOP** button has been pressed
2. Press the **Auto Transitions** toggle switch
3. Manual analysis consists of positioning a pair of crosswire cursors on the graph at the lower and upper transition points and recording the difference in power between the two points. These cursors are tracked; i.e. they follow the signal trace in manner described in the section **Automatic analysis process**.

Assessment of experimental uncertainty

The uncertainty calculations in the Results table are based on the recommendations in JCGM100: *Evaluation of measurement data — Guide to the expression of uncertainty in measurement* [3]. Total Uncertainty, U_{Total}, has a number of components that are combined in quadrature according to

$$U_{Total} = \sqrt{U_{Systematic}^{2} + U_{RFB\_Cal}^{2} + U_{Random}^{2}}$$

Term	Description
$U_{Systematic}$	Assumed to be 5% (based upon many years use of the RFB)
U_{RFB_Cal}	RFB calibration uncertainty (shown on calibration certificate)
U_{Random}	$U_{Random} = \frac{100\sigma_N T_{FACT}}{\langle P\rangle\sqrt{N-1}}$
$\langle \boldsymbol{P} \rangle$	Arithmetic mean measured power $\langle P\rangle = \frac{\sum_{i=1}^{N} Power_i}{N}$

Table 6 – Components used in uncertainty calculation

Within Table 6 the following variables are used:

N = Number of measurements

σ_N = Standard deviation

T_{FACT} = is the Student's t-factor corresponding to the number of measurements.

DATA STORAGE

There are two options for saving data – raw data and a results summary.

The raw data contains a full measurement dataset in CSV (comma-separated text) format, which can be imported directly to Excel. The following information is included:

- Signal source / transducer information
- Calibration data
- Measurements
- Analysis algorithm information
- Raw and analysed data

the results summary contains only configuration settings and the power measurements.

AFTER MEASUREMENTS ARE COMPLETE

Once measurements are complete please observe the following steps

- Close the RFB software
- Disconnect the balance from the main power supply
- Consider emptying the water vessel of the Radiation Force Balance.

- If you do not anticipate using the Radiation Force Balance within the next week, or if the water has been in the vessel for longer than 7 days and is not part of a recirculation water treatment system, empty the water from the vessel
- If the Radiation Force Balance will be used again within the next 7 days, leave the target in the water to avoid the need to re-soak the target.

ENVIRONMENTAL CONDITIONS

Unwanted changing forces which may be detected by the RFB include mechanical vibration of the support, movement or vibration of the transducer, direct wind forces, static electricity, magnetic fields, changing immersion depth of the transducer, changing water temperature, or progressive wetting of the transducer or clamp by capillary action. All of these should be minimised to obtain the lowest uncertainties.

Airflow

It is important to minimise changes in the airflow around the target, as this can increase the uncertainties in the measurement of radiation force due to a variety of environmental effects. The use of the supplied draught shield improves the performance of the RFB in a number of ways and should always be used for lower power measurements.

Sources of external vibration

Particular care should be taken to avoid vibration of the supporting surface (which is often caused by people walking heavily nearby, building vibration, fan-cooled equipment on the same surface or pressing the on/off button for the ultrasound) and of the transducer (which is often caused by a disturbed transducer cable, a slipping transducer or a loose clamp). Provided reasonable care is taken, it should be possible to obtain a very consistent rate of change in indicated mass which is due only to the slow change in the water temperature and target heating.

All RFBs are responsive to vibration and movement. Throughout the set-up and measurement procedure it is important to keep vibration to a minimum by closing all doors to the laboratory, fastening cables with appropriate ties and ensuring no movement occurs to the table which the balance is on. It may be necessary to switch off air conditioning to reduce type B (random) uncertainties for lower power measurements.

Water quality

In order to eliminate the possibility of cavitation, measurements should be performed in freshly degassed and deionised water. There are a number of methods by which water can prepared for ultrasonic measurements and the IEC Technical report 62781 [4] provides a comprehensive review of this topic.

It is estimated that water will re-gas over a period of four hours or so. For high power measurements it may be necessary to change the water every 1 to 2 hours or implement some form of re-circulation degassing.

REFERENCES

[1] IEC, *61161 Ultrasonics - Power Measurement - Radiation force balances and performance requirements,* 2006.

[2] N. Bilaniuk and G. S. K. Wong, "Speed of sound in pure water as a function of temperature," *J. Acoust. Soc. Am,* vol. 3, pp. 1609-1612, 1993.

[3] BIPM, *JCGM100: 2008 Evaluation of measurement data — Guide to the expression of uncertainty in measurement,* 2008.

[4] IEC, *62781 Ultrasonics - Conditioning of water for ultrasonic measurements,* 2015.

TROUBLESHOOTING AND FAQ

1) In the event of a suspected fault, first remove the target completely from the balance and check correct operation of the balance by using a known test mass. The internal calibration function of the balance can also be used to perform this check.

2) Turn off all unnecessary electrical equipment in the area of the balance (including signal sources, power amplifiers, computers etc). Close the draught shield and allow 20 minutes for the balance to equilibrate and then check that the balance reading is stable. When doing this ensure that you do not disturb the balance by getting too close to it. If the balance reading is unstable, it indicates that there are sources of changing electrical charge or vibration. Ensure cables to the balance are prevented from moving but are not under excessive tension. Also check for bubbles in the water, which may become dislodged from time to time.

3) Mount an ultrasound transducer so that it is 5mm to 10mm above the surface of the target and repeat the previous test with the draught shield closed as much as possible. The drift will be faster than previously but again it should be consistent - if not there are likely to be significant air currents around the balance or the transducer is introducing a problem. Check that the clamp and transducer are not touching the balance or target.

4) Lower the transducer so that the front face is approximately 10mm below the surface of the water and remove any bubbles from the transducer. Repeat the previous test. Ensure the transducer is firmly held and that the clamp itself is stable. It is quite common for the clamp to "creep" allowing slow movement of the transducer over a period of time. This can easily happen on compliant surfaces such as rubber or foam which gradually compress. A certain amount of "creep" is inevitable and is acceptable as long as it is gradual and controlled. Ensure that the transducer cable is immobilised but is not under excessive tension.

5) Turn on the electrical equipment used to drive the transducer and repeat the previous test. If this equipment causes vibration, move the balance to a separate table or trolley.

6) Now turn on any other equipment which is commonly used (including the PC used for data acquisition) and repeat the test for a consistent rate of mass decrease. If a disturbance is introduced identify the device that is causing it.

7) Carry out a measurement run of four ON-OFF periods but DO NOT turn the ultrasound on or off. It is best to stand or sit completely still during a measurement run to ensure that any movement near the balance is kept to a minimum. Now repeat the four ON-OFF periods with the ultrasound turned on and off at the appropriate times. If there is still a problem, ensure that the act of turning the ultrasound on and off does not disturb the balance.

8) If these tests have not isolated the problem, it may be that there is an electrical interaction between the transducer and the balance. Try a different type of transducer and repeat the process. If it is safe to run the transducer in air, drain the water from the target and carry out the measurement run as normal, but without the water to couple the ultrasound energy to the target. There should be no change in the display when the ultrasound is turned on or off.

Frequency asked questions (FAQ)

- What liquids can I use in my RFB vessel?
    - *The RFB is only designed for use with fresh water. An alternative liquid will have a different acoustic impedance and absorption and the measured results will be incorrect.*
    - *Degassing the water so that dissolved gas content is below 5 ppm is also recommended. For high amplitude fields degassing to a level below 2.5 ppm is more appropriate. Failure to do so may result in the formation of gas bubbles that act as reflectors and therefore introduce experimental error.*
- Do I have to soak the RFB target?
    - *Yes. Any surface immersed in water may trap macro- and micro-bubbles on its surface that will affect the measurement process. On a highly structured surface such as an RFB target, it may be very difficult to identify, let alone dislodge, these bubbles. Soaking the target is essential to ensure these bubbles have a chance to dissolve into the surrounding water.*
- How long can I leave the RFB Target in water?
    - *The target can be left immersed in water for up to a week to avoid the need to re-soak the target. However, water-borne contamination can build up on the target if left in water for extended periods so Precision Acoustics Ltd recommend removing the target from water if the RFB is not being used for more than a week*

- What can I do to check the operation of my RFB?
    - *It is recommended that the performance of the balance as a basic weighing device is checked regularly with a calibrated mass. When doing this, the RFB target should be removed from the weighing pan, and the calibrated mass placed directly on the pan.*
    - *The linearity of the balance can be checked by using a series of calibrated masses that cover the range of power typically produced by ultrasound fields (1 mg to 1 g).*
- Can high amplitude/high intensity ultrasound damage my RFB?
    - *Yes, it is possible to damage the target. However, if you follow the recommendations given in* *Preparing for measurement* *section, you should be able to avoid damage*
    - *The target should be checked periodically for damage.*
    - *It should also be cleaned occasionally by removing it from its container and wiping the surface with a soft damp cloth.*
- How often should I have my RFB recalibrated?
    - *Precision Acoustics Ltd recommend annual recalibration of the RFB.*
    - *If you are making IEC 61161 compliant measurements, or are using the RFB for the determination of ultrasound power to accompany a regulatory submission, annual recalibration is mandatory*

PRODUCT SUPPORT

Disclaimer

All information is based on results gained from experience and tests and is believed to be accurate but is given without acceptance of liability for loss or damage attributable to reliance thereon as conditions of use lie outside the control of Precision Acoustics Ltd.

Warranty

The balance is subject to the warranty of the supplier. The remainder of the system (with the exception of the absorbing material) is provided with a 12-month warranty, against defect of hardware component or manufacture only, from the date of delivery. The absorbing material is regarded as a consumable item and replacements are available from Precision Acoustics Ltd.

If a warranty claim is made on devices that have been calibrated at NPL London, the charge for calibration of the replacement device is pro-rata against the used part of the original device's 12-month calibration.

Warranty replacement after	Calibration period remaining	Discount on recalibration charge
3 months	9 months	75%
8 months	4 months	33%

Contact

Further advice, technical assistance and re-calibration can be obtained from our Applications Engineers

Address:	Precision Acoustics Ltd, Hampton Farm Business Park, Higher Bockhampton, Dorchester, Dorset DT2 8QH
Email:	office@acoustics.co.uk
Tel:	+44 1305 264669
Fax:	+44 1305 260866

Terms and conditions

PA terms & conditions are available at https://www.acoustics.co.uk/company/terms-and-conditions/