RFB-2000

Radiation Force Balance

User's/Maintenance Manual

Version 2.0.12.0
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Preface

The Onda RFB-2000 Radiation Force Balance is a precision laboratory instrument for the measurement of ultrasonic power. It is designed to be compatible with laboratory, production and field environments using contaminant free water.

The standard, non-submersible tank assembly is water-resistant and can be easily rinsed in clean water as long as the sensor cable connector is not rinsed or immersed.

The packaging is designed specifically for the RFB-2000 system to contain all system components in protective foam. It is important that the user not discard any of this packaging and that the RFB-2000 components be re-packed as delivered to assure the best mechanical damage protection.

The RFB sensor assembly is shipped with a cylindrical acrylic enclosure which serves as a handle while protecting the mechanism. Here are some important guidelines for handling the sensor:

- Always handle the sensor by the cylindrical handle or the baseplate, never by the movable float. Avoid any contact with the moving parts, except when placing the target on the float.
- When not in use, the sensor should be mated to its plastic base unit. The sensor is designed with magnets integrated to the bottom of the assembly which can cause inadvertent damage if the sensor is placed on a magnetic surface. The base provides adequate isolation to prevent such damage.
- The locking pins should be inserted if the sensor is to be transported or shipped. Insert the pins gently without forcing them. When the pins are not used, store them in the sensor base unit.
- The sensor should be handled gently at all times. Always avoid any shaking, jarring motion or sudden impact. The sensor should be removed from the water tank if not in use. It is not recommended to leave the sensor submerged for extended periods of time (e.g., > 1 week)

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1. Description

The ONDA RFB-2000 Radiation Force Balance system is designed specifically for the measurement of ultrasound power. The RFB easily handles a wide range of diagnostic, physiotherapy, and HIFU ultrasound products and laboratory devices without requiring extensive need for correction factors. The system consists of six components:

- Clear acrylic water tank with support base
- Stainless steel sensor assembly
- Acoustic target
- Electronic controller with cables
- Software application
- Optional vacuum lid and pump

The system does not include the computer, which is necessary to run the RFB software. See the Specifications for recommended minimum requirements.

Traditional scale-based methods measure the target weight in addition to the acoustic power of 67mg/watt. Onda’s sensor functions independent of leveling, water evaporation or thermal drift and, because of computer control, measurements are much more repeatable. The system is easy to set up and use, is visually transparent for easy monitoring of the test transducer, provides convenient support for transducer mounting and requires no special membranes or acoustic gel. It can be calibrated using a precision physical mass of known weight. The software provides system calibration, temperature compensation of sound velocity, measurement averaging and sequencing, sound on/off control, data collection and all other user interface interactions.

2. Features

- Transparent top-loading configuration: Transducers of most physical forms are easily mounted for testing using the rigid, vertical mount and clamp.

- Fully-Submersible Option: This tank configuration allows immersion into larger acoustic tanks to accommodate large transducer configurations.

- No membrane or coupling gel required: Transducer coupling to the sensor is easily viewable through the clear acrylic tank for easy removal of bubbles.

- Unaffected by water evaporation: Since the sensor and target are operated in balance; the measurement is completely decoupled from the water environment.

- User-calibrated to a standard mass: A single-point calibration can be obtained very easily using the included 1.0g reference mass.

- Calibration certificate to acoustic power: A single frequency, standards lab calibrated transducer is used to provide a traceable acoustic-based calibration.

- Servo system specifically designed for ultrasound power measurements: The firmware-based servo control loop is tuned for ultrasound power measurements with compensation for most related factors.

- Automatic temperature correction: The average water temperature is monitored to provide correction based on the change in sound velocity with respect to temperature.

- USB interface, optically isolated: To avoid grounding and related noise issues, the computer-side USB interface is optically isolated from the controller's interface which is also isolated from the sensor interface.

- MS Windows program for control, data acquisition, storage and display: The RFB user interface is a Windows application program which communicates with the RFB controller via USB.

- Selectable averaging: The acoustic signal ON-OFF time is adjustable to accommodate the effects of power level on response time and optimize accuracy by means of specifying the settling time.

- Automatic or manual measurement modes: To accommodate a variety of user systems, from research lab equipment to commercial products, two interface methods are supported; 1) automatic sequencing to turn the ultrasound source on and off and 2) an interactive, manual process is also provided.

- Device under test controllable by on-board relays or logic-level outputs: The RFB can automatically control user’s equipment by three means: 1) a TTL compatible signal of either polarity, 2) a ground-isolated, DC relay and 3) a wide-band, 50 ohm terminate RF relay will directly switch ultrasound driving signals up to 2 watts.

- Accommodates reflecting or flat absorbing targets: Three target styles are currently accommodated: flat absorbing, reflecting cone with cylindrical absorber and a “brush” target for HIFU up to 100W (40W CW).

3. Options

Target Options

A flat, absorbing target comes standard with the RFB system, is the simplest to use and handles up to 2 watts of acoustic power. The two additional target options currently available for the RFB are the cone target (RFB-CTK) with cylindrical acoustic absorber and the HIFU brush target (RFB-BTK). The different target options are described in Section 5 ("Theory of Operation").

3.1 Vacuum Lid Kit

A vacuum cover for the RFB tank is available as an accessory. The cover is designed to fit flat, aligned with the top edge of the tank. The cover includes a vacuum gauge and three-way valve for easy pumping and re-pressurization. The vacuum lid is a valuable addition to the HIFU brush target. It allows the target to be thoroughly degassed in-situ, thus eliminating the requirement to transfer the target from a separate vacuum chamber to the RFB tank. The brush target should be adequately degassed after running the vacuum pump for about 15 minutes.

Vacuum Lid

3.2 Vacuum Pump

Onda has selected a rugged mechanical vacuum pump which is fully compatible with the water vapor exposure presented by continual de-gassing of the RFB. Where such vacuum facilities are not available, this pump provides an easy solution for the RFB.

3.3 Thermal Index (1x1 cm) Mask

The TI 1x1 mask was designed to meet customer's needs when using the RFB-2000 to measure P1x1, which is the bounded output power from a 1 cm x 1cm area at the surface of a diagnostic transducer. Determination of P1x1 is a requirement of IEC 62359, ed. 2.0 ("Ultrasonics-Field Characterization-Test Methods for the Determination of Mechanical and Thermal Indices Related to Medical Ultrasonic Fields"). Ed 2.0 departs from previous versions in its specification of a 1 cm x 1cm output area, instead of a 1 cm slit. The TI 1x1 mask meets the recommendations of IEC 62359, namely:

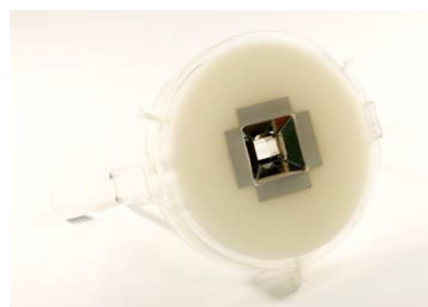
1) The mask has an attenuation of more than 30 dB above 1 MHz per Section B.4.2.
2) The mask is lined with reflective walls per section B.4.2.

In our opinion using a physical mask is the best method for making this measurement. You simply hang the mask over the rim of the RFB tank, center the transducer on the 1cm x 1cm aperture, and measure the total output power using the regular RFB assembly. Other techniques of measurement* were examined, but they would involve a greater effort from the customer, and higher measurement uncertainty (note that IEC 62359 recommends an uncertainty of less than 20% for these measurements).

* Other methods of measurement include (i) electronic masking and (ii) using a 1 cm x 1 cm target.

(i) Electronic masking applies only to array transducers and requires the preparation of special beam-forming software to turn off elements of the array outside of the 1 cm x 1 cm aperture. There are many arrays which are one-dimensional and which have an elevation width greater than 1 cm, in which case electronic masking may significantly over-predict the TI.

(ii) Use of a small 1cm x 1cm target would require substantial modifications to the RFB hardware and software, and the accuracy would suffer from the need to prevent reflections from any surface outside of the 1 cm x 1 cm target area.



3.4 RFB-STO: Submersible Tank

A fully submersible version of the RFB is designed exclusively for placement of the tank base and sensor within a larger enclosure; like a scanning system tank. This allows much larger transducers to be tested as the standard, cylindrical tank wall is not required. Any of the targets can be used with the submersible tank option.

(Note that in the photos below the sensor is not the current version, and the tank is not filled.)

Short Tank (RFB-STO)

Short Tank immersed in a larger tank to accommodate large transducers

4. Accessories

4.1 Weight Kit

The Onda RFB is a linear measurement system which can be single-point calibrated using a precision weight of known mass where the exact value in milligrams is entered in the Calibration Mass field of the application. Although the RFB can make precision measurements down to the low milliwatt levels, weights representing such levels are impractical to handle. The system includes a 1.0g mass (actual measured value of the mass is provided with each mass) which represents the force from a 14.7 watt acoustic source under ideal conditions.

Weight Kit

5. Theory of Operation

The RFB-2000 provides means for measuring acoustic power by measuring the radiation force exerted by an ultrasound beam. To achieve accurate results, there are several important aspects of radiation force theory to be considered, including:

- Target Selection
- Setup Guidelines
- Accuracy Assessment
- Certification

These topics have been thoroughly discussed in the National and International Standards and research literature [1-3]. Users of the RFB-2000 should, in particular, obtain and study the Standards [1-2] closely, although some key considerations will be described below.

5.1 Target Selection

5.1.1 Nomenclature

P = Power of an ultrasound beam
F = Radiation Force of an ultrasound beam
c = Speed of sound in the medium
θ = Angle of a collimated beam relative to a flat target
a = Radius of a spherically focused ultrasound source (1/2 its diameter)
d = Focal length of a spherical focused ultrasound source
β = Focus (half) angle of a spherically focused beam, where $\beta = \arctan(a/d)$

5.1.2 Flat absorbing target

The standard RFB-2000 includes a flat, absorbing target which is rated for power levels up to 2 Watts and can be used for either focused or un-focused beams. The absorbing material in the flat target was developed for radiation force measurements at National Physical Laboratory in the UK [4]. It is fully compliant with U.S. and International Standards for radiation force balance measurements [1,2,4].

Prior to the initial use of any target, the system must be calibrated following the procedure described in the "Calibration" section of this manual. Calibration is performed using a known mass to generate a calibration constant so that the system accurately reads the force on the target. This force is then converted to power by the software using the following formula:

$$P = c\,F \qquad (1)$$

where (c) is the speed of sound, calculated by the software based on standard formulas [4] for pure water as a function of temperature. Water temperature is measured by a temperature sensor internal to the RFB-2000 tank assembly.

Strictly speaking, Eq. (1) is valid only for a plane wave normal to a target of infinite area. However, Eq. (1) is also approximately valid for finite targets and moderately focused beams, provided that the following sources of error are considered:

- Any portion of the beam's power falling outside of the target will not be measured.

- In general, Section 5.3 of [1] advises that the target diameter should be larger than 1.5 times the nominal diameter of the ultrasound beam (the nominal diameter is the transducer diameter (2 a) for collimated beams; for focused beams, the nominal diameter at a given pre-focal depth z may be calculated as (2 a) * (z – d) / d. However, some portion of the beam is invariably not intercepted by the target, so either theoretical or experimental estimates of the proportion of energy missed is necessary for a rigorous accuracy assessment Section A.5.3 of [1] provides formulas for theoretically estimating the amount of missing energy in the case of a circular unfocused transducer. Computer models or beam-plotting measurements may also be used for this purpose.

- If the beam is not normal to the target, the force measured by the RFB will be proportional to cosine (θ), where θ is the angle of the beam relative to the normal.

- When the beam is focused, it may be thought of as the summation of plane waves which impinge on the target at different angles. In this case, the measured power will be lower than the actual power. Section B.5 of [1] suggests that the errors in the case of a spherically focused transducer may be estimated as:

  $$\text{Error} = F\,c\,[\,(\text{Cos}(\beta) - 1) / (\text{Cos}(\beta) + 1)\,] \qquad (2)$$

5.1.3 Cone Target

The optional RFB-CTK target consists of a 45 degree (half-angle) reflecting cone, and an anti-reflective cylinder which can be inserted just inside the tank wall. The cone target reflects a vertical beam horizontally into the anti-reflective coating, which has been designed to give an energy reflection coefficient of less than 1%, in accordance with Section 5.5 of [1]. The cone target is rated for powers up to 20 Watts.

Cone targets are recommended only for collimated or weakly focused beams where Eq. (1) still applies. The considerations of beam area and alignment stated in notes (1-2) for the flat target also apply to the cone target.

Due to the complicated reflection and diffraction from the cone for a focused beam, the correct formula to relate the force on the cone to actual beam power is not well-established (See Section B.6 of [1]). Consequently, cone targets are not recommended for well-focused beams. Specifically, Section 5.2.3 of [1] says that a cone target should not be used if ($d < 32\ a$), where (d) is the beam's focal length and (a) is the radius of the transducer.

The calibration result obtained for the flat target may be used for the cone target.

The cone easily installs similarly to the flat target and the self-supporting absorber fits easily between the target the tank wall. Due to the large volume displacement of the absorber, it is helpful to install it prior to completing the tank fill process.

5.1.4 Brush Target

The optional RFB-BTK target is recommended for HIFU measurements; i.e., for focused beams with power over 2 W. It is not recommended for measurements below 100 mW. The design is identical to that reported by several researchers, including a team at the United States Food and Drug Administration [6-7].

To avoid large standoff distances and excessive heating of a single spot area of the target, positioning of the brush target surface within the pre-focal region [7] is recommended. Be aware that the beam must be well-contained within the target area for accurate results, as discussed in Note (1) under the section for Flat Targets. Notes (2-3), listed under the Section on Flat Targets, also still apply.

A further consideration for HIFU is to avoid damaging the target with cavitation or excessive heating. Exposure limits for the brush are not well-established at this time, being a function of frequency, beam power, and area. At Onda, we have found that for a 1.5 MHz F/1.5 source, of diameter 10 cm with a target distance of 5 cm from the transducer, that power levels up to 40 Watts CW (i.e., 2 seconds on/off cycle, with 40 Watts when on) are achievable without target deterioration. It is also possible to use a tone-burst approach to effectively measure pulse average intensities that are much higher than the temporal average intensity [6].

It is important to degas the brush target to ensure that no air is trapped within the bristles. This may be accomplished by immersing the brush target in a container of water and placing that container in a vacuum chamber at 14 Torr or lower for 15 minutes or more. It is common to see the brush float during this process, because trapped air will expand and, because if the pressure is lower than the water vapor pressure, the water will boil. Cycling the pressure two or three times by opening and closing the pressure release valve during this process is a good idea to shake loose trapped bubbles. After degassing, it is important not to leave the brush in air as it will again entrap air if it is left to dry too long. Direct transfer between the container to the RFB tank is advised. Alternatively, Onda provides a vacuum lid (Option RFB-VLK) and water-compatible vacuum pump so that the degassing may be performed inside the RFB-2000 chamber. This avoids having to transfer the target from a separate vacuum chamber.

Tank and Sensor with Brush Target

5.2 Setup Guidelines

The following list provides some general guidelines that are useful in constructing a repeatable measurement environment:

- Onda recommends placing the RFB-2000 tank in an environment with minimal vibration to minimize the random error in the measurement.
- For proper functioning, the RFB-2000 should always be operated with the sensor in position and a target on top of it, and with the tank filled with water to a level at least 1 cm above the top of the target.
- For measurements above 1W, degassing of water is recommended, as discussed in Section 6.3 and Appendix D of [1].
- The transducer should be held securely, with minimal chance of movement or vibration. The RFB-2000's integral clamping arm is intended for this purpose.
- In general, minimal transducer-to-target distance is desirable to avoid acoustic streaming effects. However, for an absorbing target, it is advisable to keep a separation of more than 8mm to avoid the potential of thermal coupling between the target and transducer (see Section A.6.2 of [1]).

- Above all, it is important to make sure that there are no bubbles trapped at the transducer surface. The clear tank of the RFB-2000 makes inspection of the transducer surface very easy, for this purpose.

5.3 Accuracy Assessment

As discussed in [1,2], measurement errors are of two kinds: random and systematic.

Appendix A of [2] discusses techniques for estimating the random uncertainty. The statistical output of the RFB-2000 software provides an automatic means of acquiring the raw data for estimating the random uncertainty. The user is advised to study Appendix A of [2] in order to be able to successfully estimate the random uncertainty.

As described in Section 7 of [1], the systematic errors depend greatly on the particular measurement conditions. Some key factors have been discussed above in Section A, such as estimating the portion of the beam not intercepted by the target and focusing errors. These and other individual contributions must be assessed by the user for his particular measurement. Section 7 of [1] provides an in-depth discussion of typical considerations and techniques for assessing error sources.

Once the random and systematic uncertainties are determined, they are combined on an RMS basis, i.e., if (Ur) represents the random uncertainty and (Us) represents the systematic uncertainty, the total uncertainty is calculated as sqrt ($Ur^2 + Us^2$), as discussed in Appendix A of [2].

5.4 Certification

While calibration with a reference mass provides a precise and accurate reference to an ideal acoustic pressure, a calibration certificate is provided for a single frequency and power level as generated by a traceable acoustic source which is applied to the flat absorbing target. The Onda source is calibrated by an international standards lab which provides traceability to the RFB-2000. This calibration thus provides a single, acoustic-based reference measurement for validation. The calibration does not guarantee that other devices, other frequencies, other power levels and other targets will not incur additional errors relative to this single reference point.

5.5 References

1 IEC 61161, Ultrasonics—Power measurement—Radiation force balances and performance requirements, International Electrotechnical Commision, Geneva, Switzerland, 2nd ed. Dec. 2006

2 AIUM/NEMA, Acoustic Output Measurement Standard for Diagnostic Ultrasound Equipment, American Institute of Ultrasoiund in Medicine, May 1998

3 Beissner, K., " Radiation Force and Force Balances", in Ultrasonic Exposimitry, M. Ziskin and P. Lewin, eds., CRC Press, Ann Arbor, Michigan, 1993., pp. 128-142

4 Bajram Zeqiri and Catherine J. Bickley, "A new anechoic material for medical ultrasonic applications," Ultrasound in Medicine and Biology, Vol. 26, No. 3, pp. 481-485, 2000.

5 Marczak, W. "Water as a standard in the measurement of speed of sound in liquids," Journal of the Acoustical Society of America, vol. 102, No. 5, Pt 1, Nov. 1997, pp. 2776-2779

6 Maruvada, S., Harris, G.R., Hermann, B.A., and Kink, R.L., "Acoustic power calibration of high-intensity focused ultrasound transducers using a radiation force technique", Journal of the Acoustical Society of America, vol. 121 No. 3, March, 2007, pp. 1434-1439

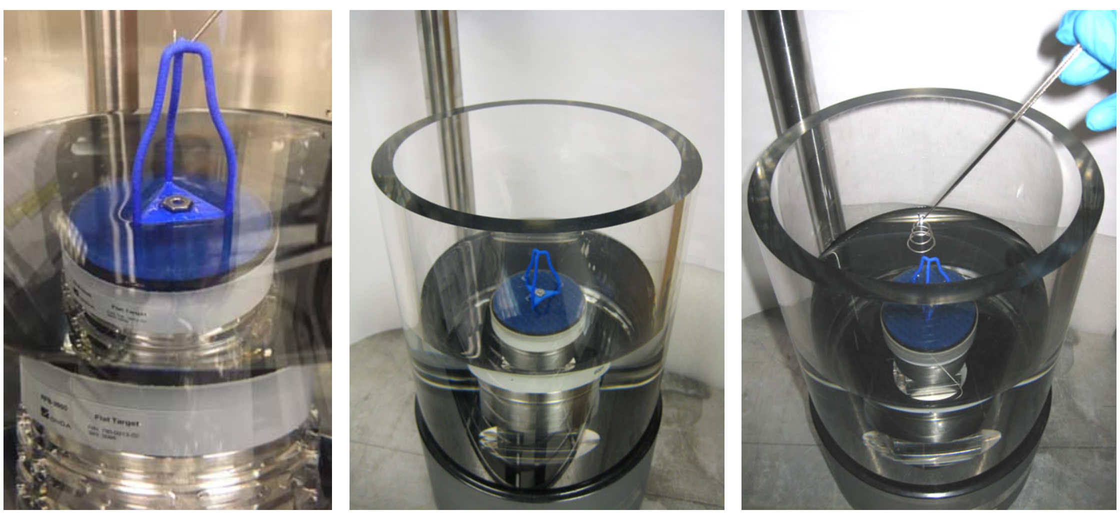
7 Hynynen, K., "Acoustic power calibration of cylindrical intracavitary ultrasound hypothermia applicators," Medical Physics, vol 20, 1993, pp. 129-134.

6. Measurement Overview

Software-based measurement using the RFB system is described by the process of manual calibration followed by either the manual or automatic measurement modes. Weight-based calibration and manual measurements require the user's physical interaction throughout each process. Measurements are performed manually when automation of the user's device is not possible.

6.1 Manual Calibration

With the standard, non-submersible tank, the target is submerged and a stand allows placement of a calibration mass with known in-air weight. A very light weight plastic stand, one end in the water on top the sensor and one end is typically out of water, allows the user to apply a calibrated standard weight to simulate a constant ultrasound power. Any mass between 0.1g and 5g can be used as the results are linear, but it is best to use a mass over 0.5 gm to minimize mechanical vibration noise in the measurement. The user is prompted when to place a weight on the stand and when to remove it.



Placing the plastic stand on the target, and placing the 1 gram mass on the plastic stand for calibration.

Multiple measurement cycles are allowed to average out random variations in the measurement. With each successive measurement, both the standard deviation and 95% confidence interval are calculated and displayed. As the number of measurements increases, the 95% confidence interval decreases. A minimum acceptable 95%

confidence interval may be set, which then causes the program to request the repeated application of the mass until that 95% confidence interval is achieved. Alternatively, the user can independently control the number of iterations.

Upon completing the calibration, a constant is set and used for all subsequent measurements. The calibration constant is also stored in a calibration log file, in units of Amps per Newton, and automatically loaded the next time the program is started. This provides a static, single-point force calibration so it is best if the weight's force due to gravity is similar in value to the expected ultrasound radiation force to be measured.

6.2 Manual Measurement

Manual measurements are performed with the user being prompted when to turn the ultrasound signal on and off, as in the case of the Manual Calibration. This mode is necessary when the user's device cannot be interfaced to any of the logic or relay controls.

6.3 Auto Measurement

The simplest and preferred measurement process is provided by allowing the RFB electronics to control the ultrasound signal of the user's device using the RFB's DC relay, RF relay, or logic (0, 5V) control. Logic signals of both polarities provide ON and OFF signals. The DC relay contacts provide DC voltage switching using completely isolated lines. The RF relay provides symmetrical, 50 ohm terminated RF signal control with very high signal isolation in the OFF state. A typical use of the RF relay is to connect the output of a function generator to the relay input, then connect the relay output to the input of a power amplifier. The output of the power amplifier is then connected to the transducer under test.

7. Installation

7.1 Environment

7.1.1 Vibration

Onda's RFB is an extremely sensitive measuring instrument which minimizes measurement noise through common-mode coupling design. Even so, measurement of very low power levels can be significantly improved by intelligent placement of the tank on a solid surface away from vibrational sources. Heavy laboratory counter tops and rugged benches away from mechanical equipment are advisable.

The RFB demands a minimum of its environment other than a clean, flat work surface, free of harsh chemicals which might degrade the tank plastic materials and an area with minimal vibration. If a vacuum pump or system is used for de-gassing, it is recommended that the pump and other mechanical systems be turned off during measurements to minimize vibration.

7.1.2 Computer

Onda recommends the controller be connected to a computer with the following list of capabilities:

- An available USB (1.0 or 2.0) port with type-A connector
- At least a 1 GHz CPU with 256Mb of RAM
- Windows 7 32- or 64-bit, or Windows 10 64-bit operating system
- A CD-ROM drive

7.1.3 Power

The RFB controller supplies all signals and power except for the computer side of the controller's USB interface whose DC power is provided by the computer via USB. The controller's power supply will operate on 90 - 264 VAC, 47 - 63 Hz, and only requires the appropriate power cable.

7.1.4 Water

While the RFB will perform well with tap water, Onda recommends the water be de-ionized and de-gassed in accordance with the frequency and power limits of the tests being performed. For proper functioning, the RFB-2000 should always be operated with the water level at least 1 cm above the top of the target.

7.1.5 Tank Cleaning

The RFB tank materials are rugged but not designed for accepting any fluid other than water. The tank can be cleaned with normal soap and water. The only other product recommended for cleaning the clear tank walls is “Brillianize” as other products could cause scratching or crazing. (See http://www.brillianize.com/) Never use alcohol, acetone or abrasive products to clean the tank.

7.1.6 Vacuum

De-gassed water is beneficial for improving the acoustic measurement environment in general. Water can be de-gassed before being used to fill the tank, or it can be degassed in situ with the use of the degassing lid and a suitable vacuum pump. (See section 4.2)

De-gassing becomes very important when measuring higher power present to some extent in conventional therapeutic ultrasound and especially in HIFU, where cavitation is likely to occur unless the dissolved gas content is very low. Also, when using the brush target, the target itself will need to be degassed to remove any air trapped amongst the bristles which may create undesired acoustic reflections affecting the measurement.

7.2 Connections

7.2.1 Tank

The standard tank connects to the controller through a single cable which attaches to a circular, water-resistant connector in the side of the tank base. The connector is not water-proof and while the tank can safely be cleaned with water, Onda recommends against immersion of standard tanks for cleaning. The submersible tank option does not have this restriction.

7.2.2 Controller

The controller connects to the computer by means of the provided 2 meter USB A-B cable. The USB interface in the controller is signal and power isolated from the computer and therefore powered from the computer’s own USB port. For additional noise immunity, the sensor is signal, power and ground isolated from the computer interface.

In following this procedure for initial system connection, do not connect the USB cable at this time.

7.2.3 AC Power

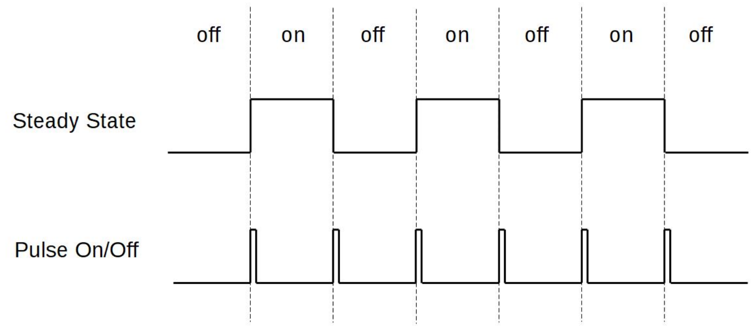
Connect the controller to AC power with an appropriate power cable.

7.2.4 Power On/Off Controls: Logic level and DC and RF Relays

The controller provides three means for synchronizing the ultrasound source with the measurement cycle.

- Two BNC connectors provide active-high (5V) and active-low (0V) logic signals.
- A set of three Banana-Jack/Binding Post connectors provide access to a fully isolated DC relay that can switch up to 24 volts and 1 amp of current.
- Two additional BNC connectors provide access to a 50 ohm input and output terminated RF relay which provides direct signal switching up to 2 watts. When in the off state, both BNC connections will be connected to ground through 50 Ohms. When in the On state, there will be a direct connection between the two BNCs.

There are two available control modes: Steady State, and Pulse On/Off:

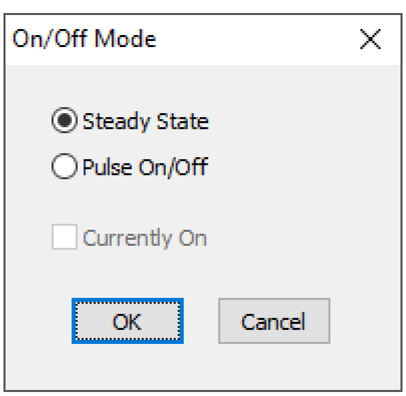


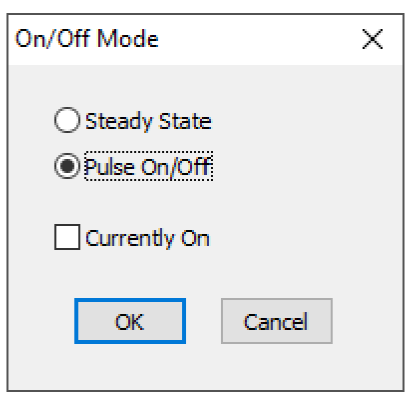
The front-panel LED, the logic level outputs, and the DC and RF relays will change state at the same time. In Steady State mode, when in the On state:

- The active-high logic-level output will be high, active-low output will be low.
- The DC relay ‘NO’ (normally open) output will be connected to the DC relay ‘C’ (common).
- The RF relay will be connected in the “through-path” with no 50-ohm loading.
- The front panel LED will be lit.

In Pulse On/Off mode, there is a positive-going pulse for each transition. This pulse is about 100 ms in duration. The DC relay can therefore be used to simulate closure of a “freeze” foot switch. The RF relay is not very useful when operating in Pulse On/Off mode.

The On/Off control mode can be selected by clicking Setup / On/Off Mode, which displays this dialog box:





When using Pulse On/Off mode, before starting a measurement, the ultrasound machine On/Off state needs to match the state in the RFB software. The is can be set using the Currently On check box shown above.

7.3 Tank and Sensor

7.3.1 Sensor Assembly

The sensor mechanism is relatively fragile and should be handled carefully to minimize mechanical shock. Always use the protective cage to handle the sensor.

RFB Sensor and Base

7.3.2 Install Sensor

While the sensor can be installed into a dry tank, it is easier to observe trapped air bubbles under and around the sensor when the tank has been partially filled. A simple starting volume is to fill to a depth roughly equal to the height of the sensor and then install the sensor.

The sensor mechanism will only fit the base of the tank in one orientation; the slot in the base of the sensor fits the square-ended pin which protrudes from the tank base metal plate. The other (pointed) pin fits in the opposite hole in the bottom of the sensor. Screws on the bottom of the sensor provide a three-point contact for stability but the mechanism is light enough in water that little side force is required to tip the sensor. Simply ensure the sensor is fully seated and not impinging on any other surfaces.

7.3.3 Visual Checks

After the sensor is placed, visually check for trapped bubbles and remove them. The sensor can easily be lifted in place, and a gentle side-to-side or swirling motion will often dislodge trapped bubbles. Additionally, a syringe with nozzle is provided in the kit to aid in this process.

7.3.4 Water Level

Depending on the water level in the tank, more water may need to be added so that the level is sufficient to cover the target with at least 1.5 – 2.5 cm height of water when the target is added. If your plan is to calibrate with the standard mass platform, the goal is to have about 1 cm or so of water above the flat absorptive target. This will allow easy placement of the standard mass platform on the target for calibration. You can then add water to the desired level for the separation between your transducer and the target.

7.3.5 Installing Target

The targets are designed to minimize trapping bubbles, but as with installing the sensor, the clear tank allows for easy verification. The sensor and target have internal magnets which securely hold the target in position. The three bottom pins on the target are designed to fit within the recessed center area of the sensor float to help keep the target aligned.

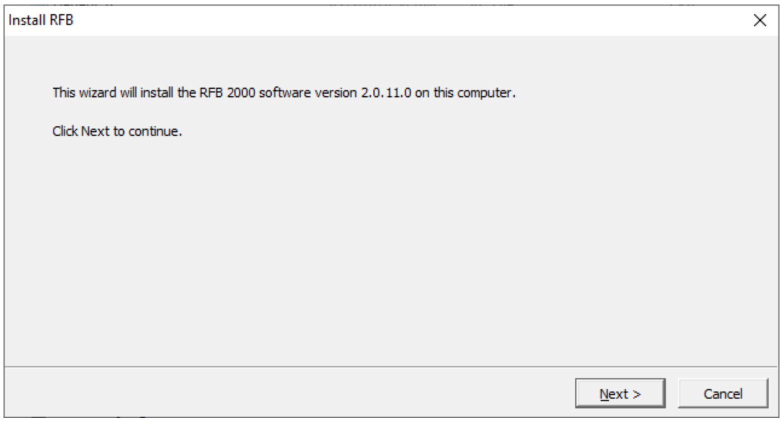
7.3.6 Checking Buoyancy

Now that the sensor and target are installed, very gently perform a visual check of the sensor mechanics to observe the buoyancy of the combined sensor and target. Ideally, the combination is neutrally buoyant though if there is a slight tendency to either sink or float, the controller will be able to automatically compensate.

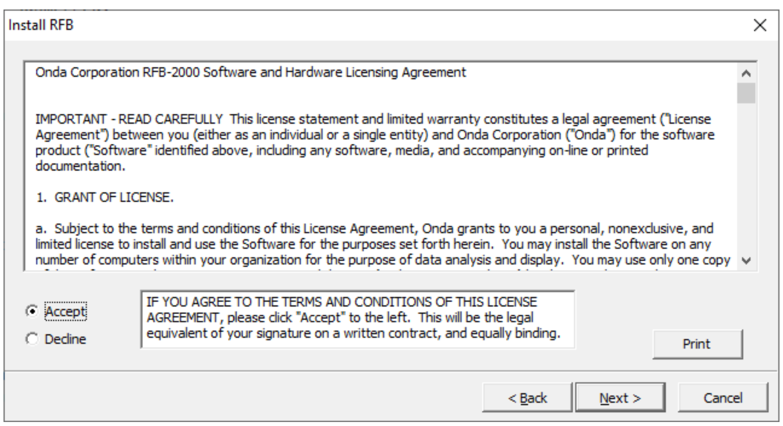
8. Software Installation

8.1 RFB Software

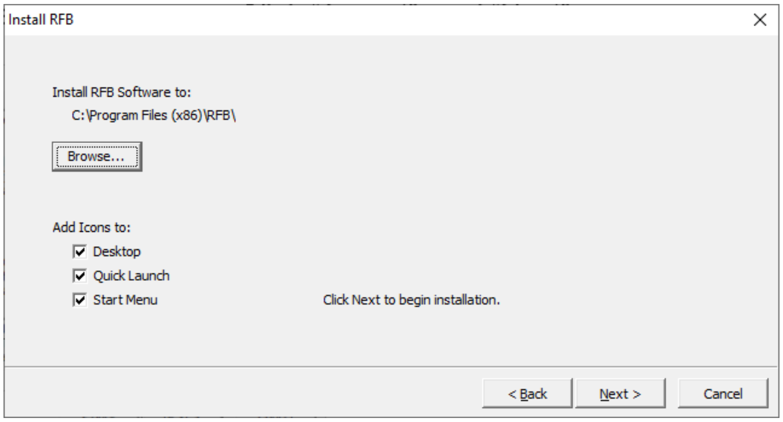
To install the RFB software, run the RFB installation program. It will be named "InstallRFBx.x.x.x.exe", where x.x.x.x is the version number. When it starts, you will see something like this:



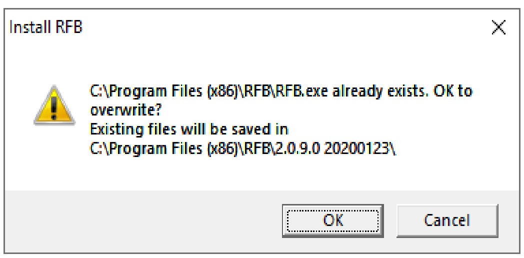
After clicking "Next", the license page appears. Click "Accept", and "Next".



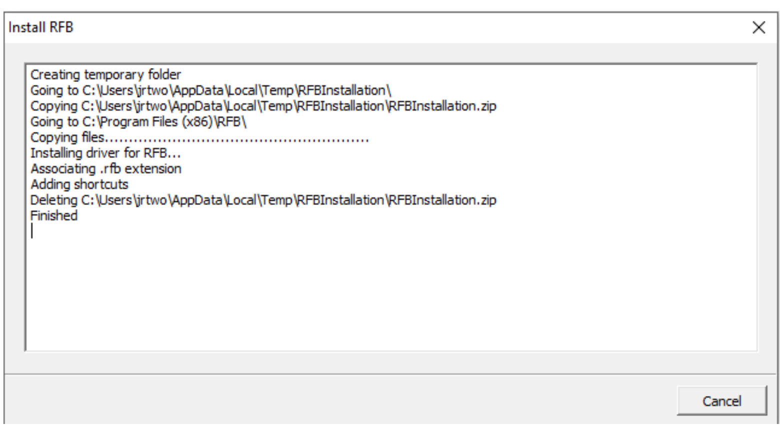
You will then be shown where the RFB software will be installed. You can change the location if desired by clicking “Browse”.



If a previous version is already installed, you will be warned, and shown where the existing files will be saved.

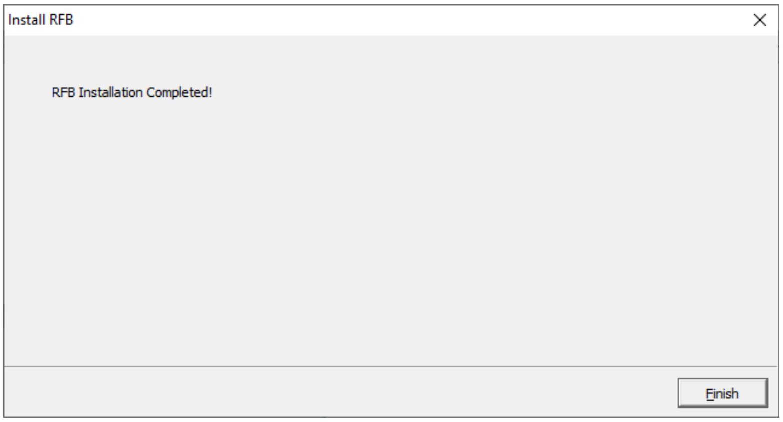


You will then be shown progress as the program installs:



During installation, the driver for the FTDI USB-serial converter will be installed, which may cause security warnings to be displayed.

Once completed, you will see this:



Click “Finish” to close.

8.2 Sumatra PDF Reader

The RFB-2000 software uses Sumatra PDF Reader to view the manual in response to Help menu items and the F1 key. Sumatra PDF Reader is open-source, available as an installer, or as a self-contained portable EXE file. The self-contained EXE is installed when the RFB software is installed, in the same folder as RFB.exe. More information is available at:

https://www.sumatrapdfreader.org/free-pdf-reader.html

8.3 Connection and USB Driver

The RFB controller contains a USB to serial interface module, the USB232M which uses the FTDI chipset. This chipset is also used in some USB to serial adapters. With the current version of the software, in most cases the RFB should be the only device that uses this chipset connected to the PC controlling the RFB. The RFB can, however, be connected to the same PC as an Onda EMDS-USB (part of the AIMSIII) with no problem.

The driver for the USB232M is installed by the RFB installation program. Once installed, connect the RFB to the computer, and Windows will detect the new hardware and copy the driver files to a folder where they will be accessible.

8.4 Power-up

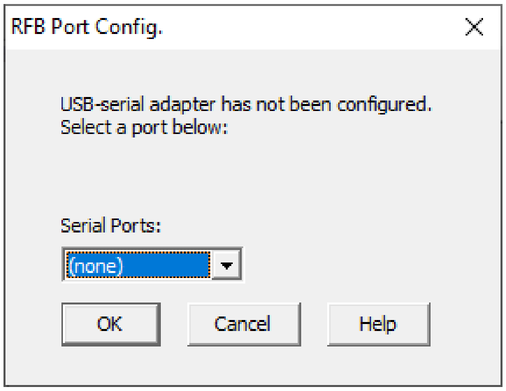
With the sensor and target now installed and the sensor, USB and power cables plugged in, the controller is ready and can now be switched on using the controller's front panel power switch. The green LED power indicator should light.

Note: the RFB software will start in "simulated" mode if the controller is not connected to the PC, or the controller is not turned on. See section 11.

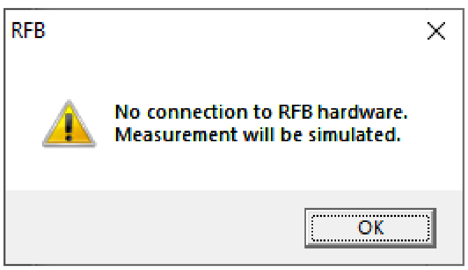
9. Software Features

9.1 Starting the Program

The RFB software performs several checks on the RFB hardware when it starts.
It first checks if the USB-serial converter is configured. If not, you will see this:

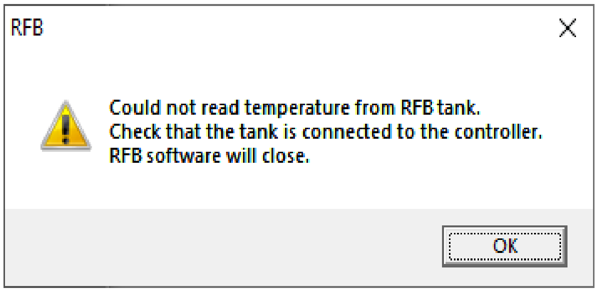


Next, it checks if the RFB controller is responding. If not, you will see this message box:

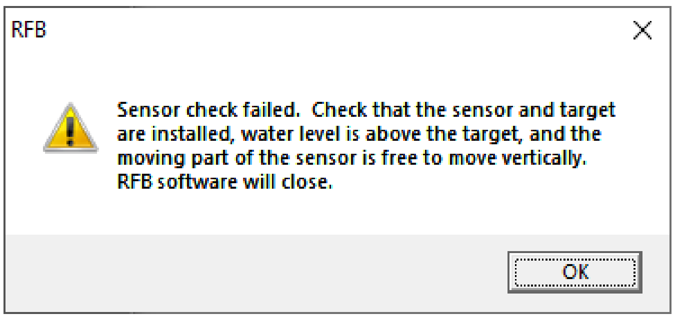


If the RFB software is running in "simulated" mode, you will need to close it, correct any problems, and re-start it so that it will connect to the hardware.

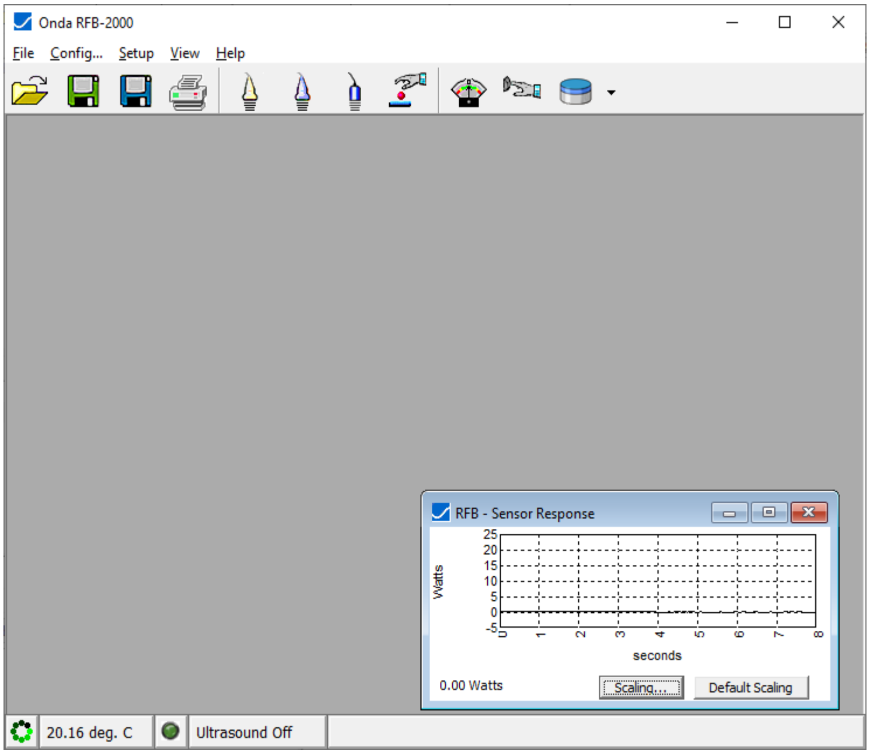
Next, it checks if the tank is connected to the controller. If it cannot read the temperature from the sensor in the tank, you will see this message box:



If the controller and tank respond, then it checks the sensor response. The result of this check is saved to a log file, and can be used to verify stability of the sensor over time. If the sensor check fails, you will see this message box:

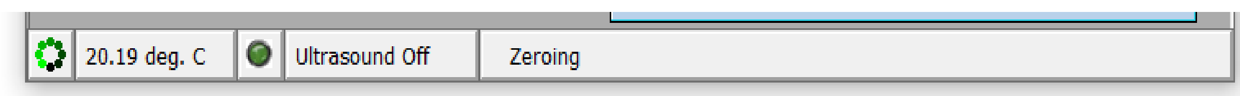


Once the sensor check is completed, a window opens that shows the response of the sensor over the most recent eight seconds.



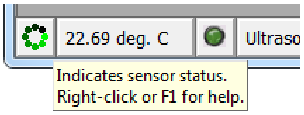
9.1.1 Status Bar

At the top of the main window are the menu bar and a toolbar. At the bottom is a status bar which displays a sensor status indicator, temperature, ultrasound on/off status (as an LED and text), and a fifth area that displays status during the sensor check and while zeroing, as well as other status messages:



The sensor status indicator should be green and rotating about once every two seconds. If it is red, that means that the sensor is not in its normal operating range. If it is not rotating at the normal rate, there may be a problem with communication with the controller. If it is not green and is not rotating consult the troubleshooting guide.

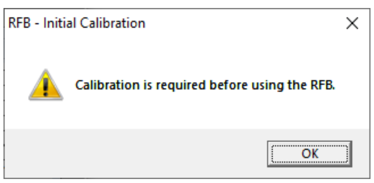
The sensor status indicator and the other panels display hints when you move the mouse over them. Right-clicking the panel or pressing F1 will display this section of the manual. This is the hint in response to moving the mouse over the sensor status indicator:



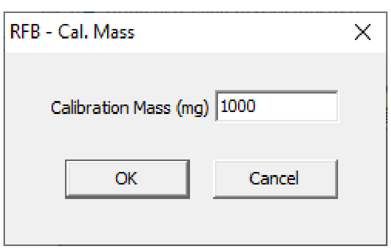
If the tank water temperature is above or below room temperature (defined here as 17 to 28 degrees C), the temperature panel's text will change color to red if too high, and to orange if too low.

9.2 Initial Calibration

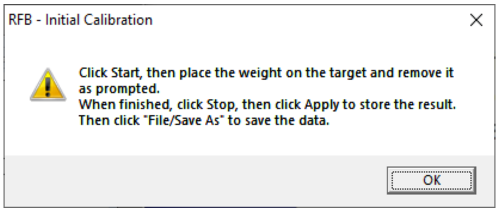
The first time the program is run, a message box will appear reminding the user that calibration is required. Place the RFB calibration platform vertically on the submerged target, where half of the platform is above water and half below. Click OK.



A dialog box will appear where the known weight in air, in milligrams, of the calibration reference mass is entered.

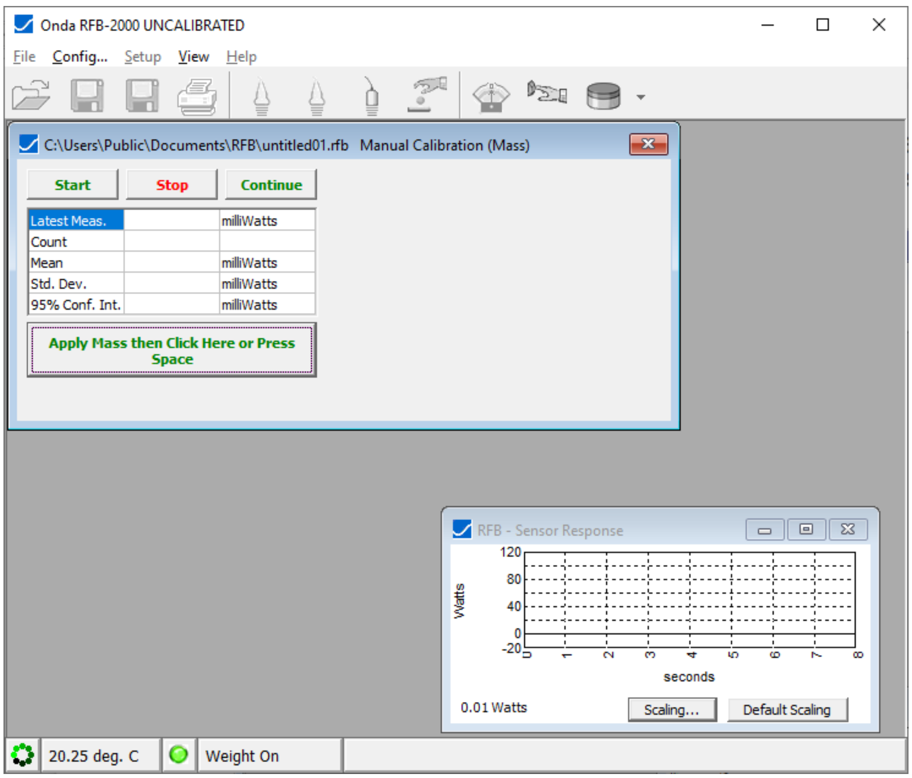


Upon clicking OK, the Manual Calibration sub-window will be displayed and this message box will appear:

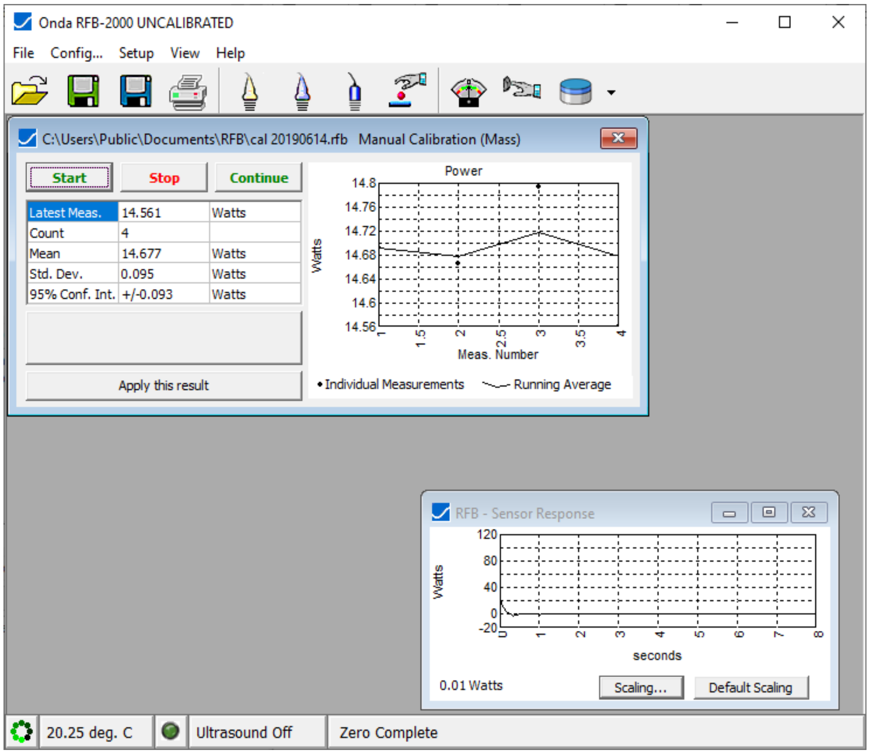


Click OK to acknowledge the instructions.

When you click Start, the button below the table will read “Wait…” (red text). After two seconds, it will change to “Apply Mass then Click Here or Press Space.”, and the text will be green. It will also play a sound when it's time to apply or remove the mass.



Place the mass on the platform, and click or press Enter or the space bar. The button will again read “Wait…”, and after two seconds will change to “Remove Mass then Click Here.”. Continue this process for several cycles, then click Stop.



At this point you can save the data file. If you click “Apply this result”, the calibration result will be stored in the program’s setup information. Once this is completed, measurements can be made.

Once the RFB has been calibrated, “UNCALIBRATED” will no longer show in the title bar of the main window.

9.3 Menu Structure

The following textual representation of the user interface menu structure is provided to assist with understanding how to navigate the RFB application.

- File
  - New
    - Auto Measurement
    - Manual Measurement
    - Auto Cal. (Ultrasound Source)
    - Manual Cal. (Mass)
  - Open…
  - Recent Files
  - Close
  - Save
  - Save As…
  - Printer Setup…
  - Print…
  - Exit
- Config...
- Setup
  - Automatically Zero
  - Zero Now
  - Target
    - Flat Absorber
    - Brush Absorber
    - Conical Reflector
    - Other
  - Device Under Test
  - Turn Ultrasound On
  - On/Off Mode
  - Cal. Source…
  - Cal. Mass…
  - Correction Factor…
  - Timing…
  - Completion…
  - Serial Numbers...
  - Options...
- View
  - Weight
  - Power
  - Position Sensor Log...
  - Calibration Log...

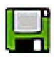
Help

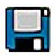
- About…
- Preface
- Contents
- Description
- Features
- Options
- Accessories
- Theory of Operation
- Measurement Overview
- Installation
- Software Installation
- Software Features
- External Control
- Specifications
- Measurement Example
- Troubleshooting Guide

9.4 Toolbar Choices

At the top of the main window is a toolbar with several buttons. Clicking on these will have the same effect as selecting the menu item as described above.

 File/Open…

 File/Save

 File/Save As…

 File/Print

 File/New/Auto Measurement

File/New/Manual Measurement

 Auto Cal. (Ultrasound Source)

 File/New/Manual Cal. (Mass)

 Setup/Zero Now

 Setup/Turn Ultrasound On

 Setup/Target (image depends on which target is selected)

When you move the mouse over any one of these buttons, a hint will appear as a reminder of the function of that button.

9.5 Menus

9.5.1 File Menu

File menu items are standard except for the three items under File/New, which open the Automatic Measurement, Manual Measurement, Auto Calibration, and Manual Calibration menu items.

- Automatic Measurements can be done when it is possible to use the logic signal outputs or the relays to control the ultrasound being measured.

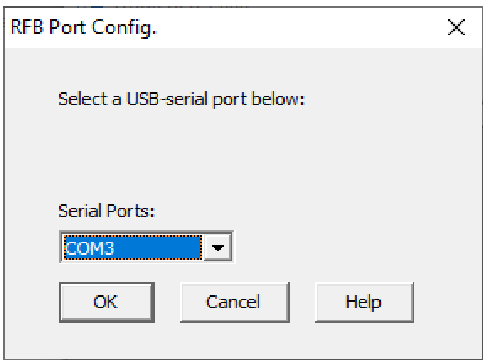
- Manual Measurements are done when it is not possible to automatically control the ultrasound.

- Automatic Calibrations are done using an ultrasound source with known output power, switched on and off using the output controls.

- Manual Calibrations are done by placing and removing a known mass repeatedly on and off a target.

9.5.2 Config Menu Item

This brings up a dialog box which allows you to select the USB-serial port that the RFB controller is connected to.



9.5.3 Setup Menu

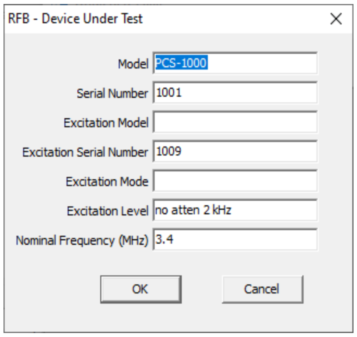
The Setup Menu offers easy access to system configuration parameters.

Automatically Zero
If this is checked, the program will periodically check if zeroing is needed and do it if so. It does not do this once a measurement has been started.

Zero Now
This starts a zeroing cycle regardless of whether Automatically Zero is checked.

Target
This lets you select Flat Absorber, Brush Absorber, Conical Reflector, or Other

Device Under Test...
This displays a dialog box that lets you enter information on the device under test.

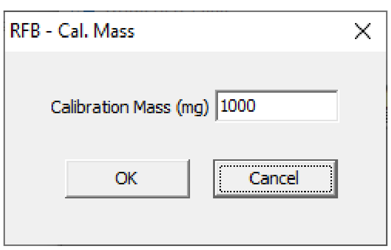


The user's "Device Under Test" and "Calibration Source" are sets of text fields which provide means to capture relevant information about the transducer and the RF signal source. This information is only for annotating the saved measurement data and is not required to make measurements.

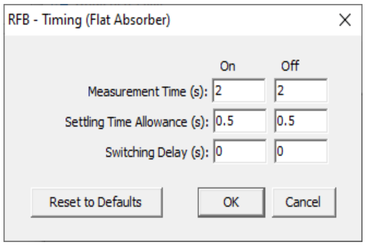
Turn Ultrasound On
This turns on the ultrasound through the front panel connections, or if it is on, turns it off. (When the ultrasound is on the caption changes to "Turn Ultrasound Off".)

On/Off Mode...
This brings up a dialog box allowing selection of either Steady State or Pulse On/Off control mode. See the section on output control.

Cal. Source... and Cal. Mass…
This lets you enter information on the calibration mass.



Timing…
This displays a dialog box that let you set the on and off times, and the time allowed for settling. The on and off times can be set independently to allow a duty cycle other than 50%. The range of values for the "on" and "off" times and the settling time allowances depend on the target type.



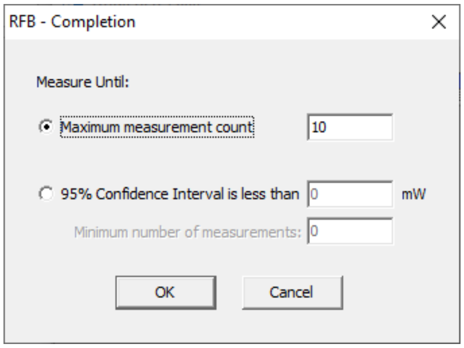
		Flat Absorber, Cone Reflector	Brush Absorber
On/Off Time (s)	Minimum	1	2
	Default	**2**	**4**
	Maximum	30	60
Settling Time Allowance (s)	Minimum	0.25	1
	Default	**0.5**	**2**
	Maximum	15	30

The minimum times directly relate to the minimum time necessary for the source, transducer and target to settle from the reaction to transitional acoustic pressure. Longer times may be required either for measuring very low or very high power levels. When measuring levels near the system’s lower power threshold, noise can only be eliminated by long term averaging. At high power, the impact of heating can affect both the water temperature and the bristles on the brush target. At very high power, not only must the Sound On time be limited but a secondary modulation must be pre-applied to the source to keep the average power within instrument limits.

The On and Off switching delays are for special cases where the ultrasound system does not turn on or off immediately in response to the control signal. The switching delays should be entered here.

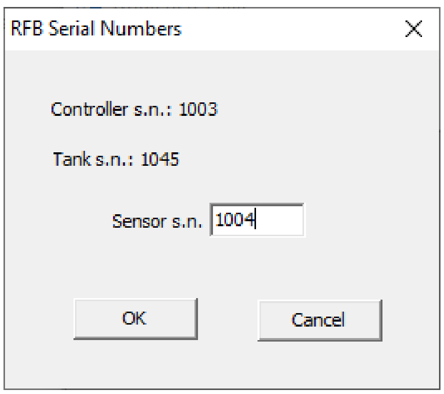
Completion…
This displays a dialog box which lets you set criteria for completion of a measurement. Completion can be based on a number of measurements or by setting a threshold for 95% confidence interval. If the value entered is 0, the measurement will continue until stopped by the user.

When the 95% confidence interval is used, you can also enter a minimum number of measurements. This is to avoid stopping in cases where the first two measurements are in much closer agreement than usual.



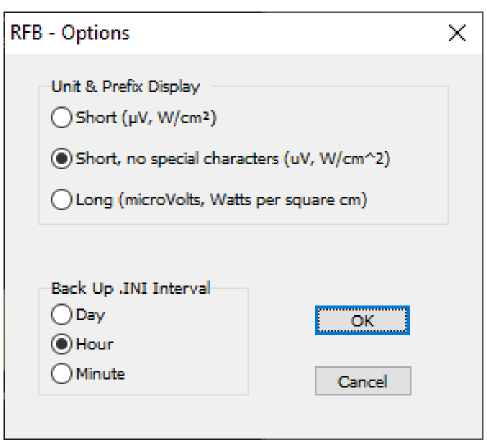
Serial Numbers…

This displays a dialog box which shows the controller and tank serial numbers. These are set during the manufacturing process, and are read by the software. The sensor serial number cannot be read electronically, so it can be entered here:



Options…

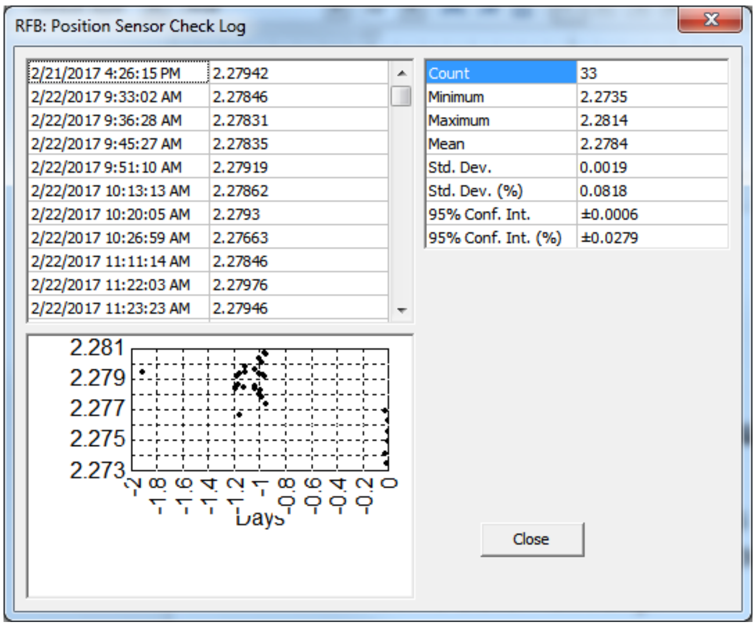
This displays the options dialog box:



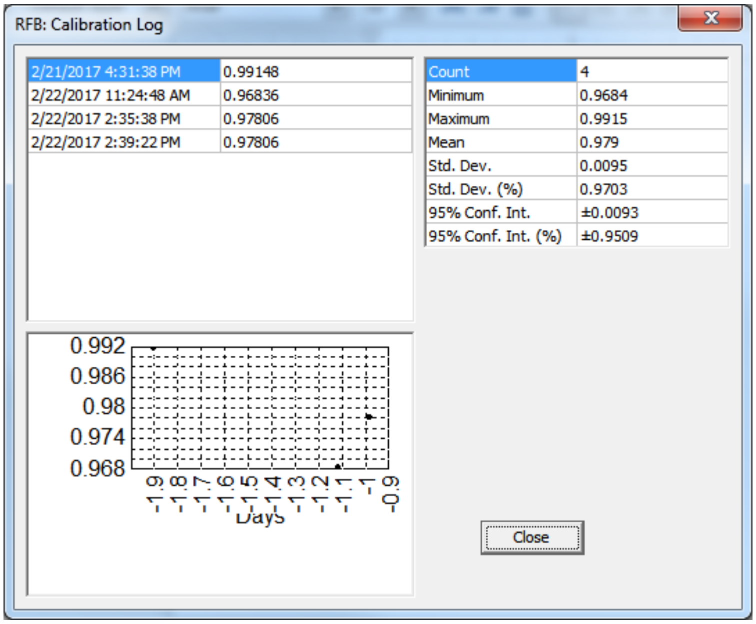
9.5.4 View Menu

Weight, Power:
The first two menu items let you select the display units, which can be weight (g or mg) or power (W or mW). The scaling of displayed values (g or mg, W or mW) is done automatically.

Position Sensor Log… Calibration Log...
You can also view the Position Sensor Log or Calibration Log. Each time you start the RFB software, it does a position sensor check, and the results are stored in a file. Each time you do a calibration, the calibration results are stored in another file. This is what you see when you click on Position Sensor Log:

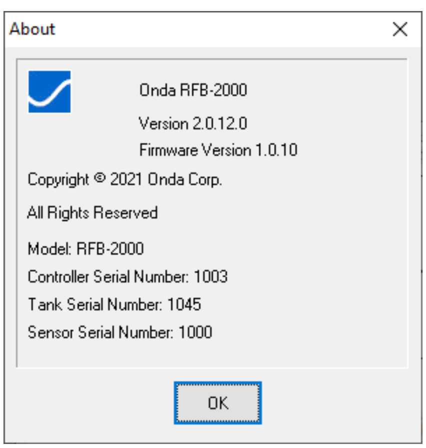


This is what you see when you click on Calibration log:



9.5.5 Help Menu

The first item is “About”, which displays the “About” dialog box:



The controller and tank serial numbers are read from the devices and displayed. The sensor serial cannot be read by software, so it needs to be entered under Setup / Serial Numbers.

The rest of the items open the manual (this document, a PDF file) to various sections.

10. External Control

This section describes the functions that are available in RFBClient.dll and RFBClient64.dll. These DLLs allows for control of the RFB software by an external program.

The controlling program may be written using any development environment that can call functions in a Windows 32- or 64-bit DLL. This includes MatLab, LabView, Delphi, some versions of C/C++, and VBA. Any development environment will require information on the parameters passed to each function and the return type if any. Onda provides interface files for MatLab and Delphi.

The calling convention for all of these functions is “stdcall”.

There are only a few simple data types used by functions in the DLL:

pansichar: a 32-bit pointer to a null-terminated string of 8-bit characters
integer: a 32-bit signed integer
longbool: a boolean, represented as a 32-bit integer (0 = false, non-zero = true)
double: a 64-bit floating point number

10.1 Connection to RFB.exe

RFBRunning: used to determine if RFB.exe is running on the computer on which the calling program is running.

OpenRFBConnection: Opens a connection to RFB.exe. It needs either the IP address or the computer name of the computer that RFB.exe is running on. It is passed 127.0.0.1 or localhost if RFB.exe is running on the same computer as the calling program. Returns true if connection is successful.

Connected: Returns true if a connection has been made to RFB.exe.

CloseRFBConnection: Closes the connection.

CloseRFB: Closes the connection and closes RFB.exe.

10.2 Version Information

These functions get the version numbers of RFB.exe and RFBClient.dll:

RFBVersion
RFBClientVersion

10.3 Zeroing, Checking Sensor

Zero: Starts the auto-zeroing process.
Zeroing: Returns true if the RFB is busy zeroing.
CheckingSensor: Returns true if the RFB is busy checking the sensor, which happens shortly after RFB.exe is started

10.4 Timing

SetOnHalfCycleCount, GetOnHalfCycleCount, SetOffHalfCycleCount, GetOffHalfCycleCount: These set/get the half cycle counts for the on and off half-cycles. Each count represents 5 ms. The optimal value is 40 (2 seconds).

SetOnSwitchDelayCount, GetOnSwitchDelayCount, SetOffSwitchDelayCount, GetOffSwitchDelayCount: These set/get the delay from the time when the RFB sound-on control input changes to the time that the ultrasound system actually starts or stops transmitting. Each count represents 5 ms. The default is 0.

10.5 Measurement

NewAutoMeasurement: This opens a new automatic measurement window. A measurement window must be open before the other functions in this section can be called.

StartMeas, StopMeas: Start and stop the measurement.

Measuring: Returns true if the RFB is busy measuring. This should be polled to see if a measurement is completed.

SaveAs: Saves the measurement to a .RFB file with the specified name.

GetMeasCount, GetMean, GetStdDev, GetSDOM: These get the number of measurements and statistical information (in W).

CloseMeasurement: Closes the measurement window. It does not close the RFB program.

10.6 Completion criteria

These functions will not work unless a measurement window is open (See NewAutoMeasurement)

SetMeasureUntilCount, GetMeasureUntilCount: These set/get the way the RFB decides that a measurement is complete, based on either completion count (true) or the 95% confidence interval (false).

SetCompletion95PctCI, GetCompletion95PctCI: These set/get the threshold (in mW) for when the RFB finishes a measurement, when MeasureUntilCount = false.

SetMinCount, GetMinCount: These set/get the minimum number of measurements required when using the 95% confidence interval to determine if a set of measurements is complete.

SetCompletionCount, GetCompletionCount: These set/get the number of measurements, used when MeasureUntilCount = true.

10.7 Low-level functions

These functions provide lower-level access to the RFB state than is usually used in measurements.

SetSoundOn, GetSoundOn: These control the front-panel outputs on the RFB controller.

GetBiasVoltage, SetBiasVoltage: These set/get the bias voltage, used for zeroing the RFB. The range is -2.5 to 2.5 volts.

GetPosition: This gets the position sensor signal.

GetVoltage, GetVRMS, GetGrams, GetWatts: These get the servo voltage or the RMS servo voltage (a measure of noise), and equivalent values in grams and Watts.

GetTemperature: This returns the temperature measured by the temperature sensor.

10.8 List of Functions

Below is a list of the functions in RFBClient.dll. This is copied from the Delphi interface file (RFBClientInterface.pas), and shows the parameters passed to each function (if any, in parentheses), and in the case of functions, the returned type.

```
function OpenRFBConnection(AHost: pansichar): longbool; stdcall;
function RFBRunning: longbool; stdcall;
function Connected: longbool; stdcall;
function CloseRFBConnection: longbool; stdcall;
procedure GetRFBClientVersion(value: pansichar); stdcall;
procedure GetRFBVersion(value: pansichar); stdcall;
procedure Zero; stdcall;
function Zeroing: longbool; stdcall;
function CheckingSensor: longbool; stdcall;
procedure SetBiasVoltage(value: double); stdcall;
function GetBiasVoltage: double; stdcall;
procedure SetSoundOn(value: longbool); stdcall;
function GetSoundOn: longbool; stdcall;
function GetPosition: double; stdcall;
function GetVoltage: double; stdcall;
function GetVRMS: double; stdcall;
function GetGrams: double; stdcall;
function GetWatts: double; stdcall;
function GetTemperature: double; stdcall;
procedure SetCompletionCount(value: integer); stdcall;
function GetCompletionCount: integer; stdcall;
procedure SetCompletion95PctCI(value: double); stdcall;
function GetCompletion95PctCI: double; stdcall;
procedure SetMeasureUntilCount(value: longbool); stdcall;
function GetMeasureUntilCount: longbool; stdcall;
procedure SetMinCount(value: integer); stdcall;
function GetMinCount: integer; stdcall;
procedure SetOnHalfCycleCount(value: integer); stdcall;
procedure SetOffHalfCycleCount(value: integer); stdcall;
procedure SetOnSwitchDelayCount(value: integer); stdcall;
procedure SetOffSwitchDelayCount(value: integer); stdcall;
function GetOnHalfCycleCount: integer; stdcall;
function GetOffHalfCycleCount: integer; stdcall;
function GetOnSwitchDelayCount: integer; stdcall;
function GetOffSwitchDelayCount: integer; stdcall;
procedure NewAutoMeasurement; stdcall;
procedure StartMeas; stdcall;
procedure StopMeas; stdcall;
```

```
function GetMeasCount: integer; stdcall;
function Measuring: longbool; stdcall;
procedure SaveAs(value: pansichar); stdcall;
function GetMean: double; stdcall;
function GetStdDev: double; stdcall;
function GetSDOM: double; stdcall;
procedure CloseMeasurement; stdcall;
procedure CloseRFB; stdcall;
```

10.9 Sample Programs

Onda provides sample external-control programs for Matlab and Delphi.

10.9.1 Matlab

Onda provides a simple Matlab demo, RFBCommDemo. There are two versions of RFBCommDemo, one for 32-bit Matlab, the other for 64-bit Matlab. The files are in the RFB data folder, which by default is

C:\Users\Public\Documents\RFB (alias C:\Users\Public\Public Documents\RFB\)

The files for the 32-bit version (in the 32-bit sub-folder) are:

RFBClentDemo.m
RFB_proto.m
RFB-MATLAB_Demo_Readme.pdf

The files for the 64-bit version (in the 64-bit sub-folder) are:

RFB64_proto.m
RFBClient64_thunk_pcwin64.dll

These will call functions in RFBClient.dll and RFBClient64.dll respectively. The DLLs are copied to appropriate folders during the installation so that they will be accessible from anywhere on the computer.

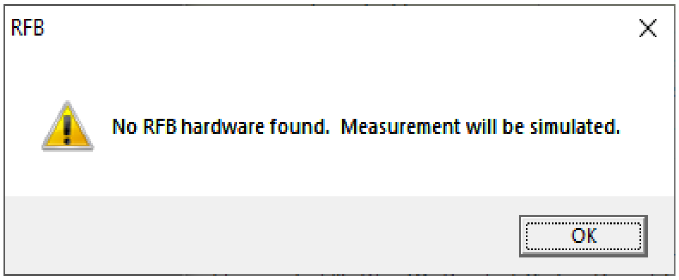
You can run the demo in two modes:

1. Simulated mode
2. Automatic measurement mode

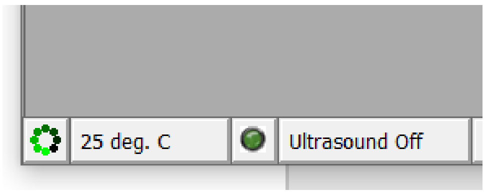
Option 1: Simulated mode

i. Ensure the RFB controller is powered OFF.

ii. Start the RFB software. Click OK on the following message when it appears:



iii. Wait for the sensor response indicator in the lower left corner to turn green.



iv. Start a 32-bit instance of MATLAB, and navigate to the folder containing the demo file(s).

v. Type *RFBCommDemo2015()* in the MATLAB command window.

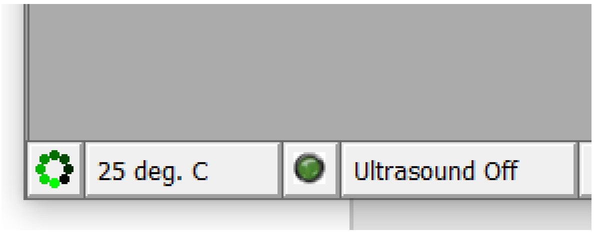
<u>Option 2: Real Automatic measurement mode</u>

i. Ensure all the hardware is connected, tank is filled, the sensor and the target are installed, and the RFB-2000 controller is powered ON. (Please refer to the RFB-2000 Manual for questions about setting up the RFB-2000 tank, sensor, target, and connections.)

ii. Calibrate the RFB-2000, if needed.

iii. Set up the test device you want to measure in the RFB-2000 tank using the automatic measurement option. (See measurement example in this manual.)

iv. Ensure the sensor response indicator is green.



v. Start a 32-bit instance of MATLAB, and navigate to the folder containing the demo file(s).

vi. Type *RFBCommDemo()* in the MATLAB command window. For more details on the available functions please refer to the External Control section in this manual.

Please note that this demo is provided on an as-is basis with no warranty. It has been tested with RFB-2000 version 2.0.2.0 and MATLAB R2014 (32-bit). If you have any problems with the demo or the RFB-2000 software, please contact Onda.

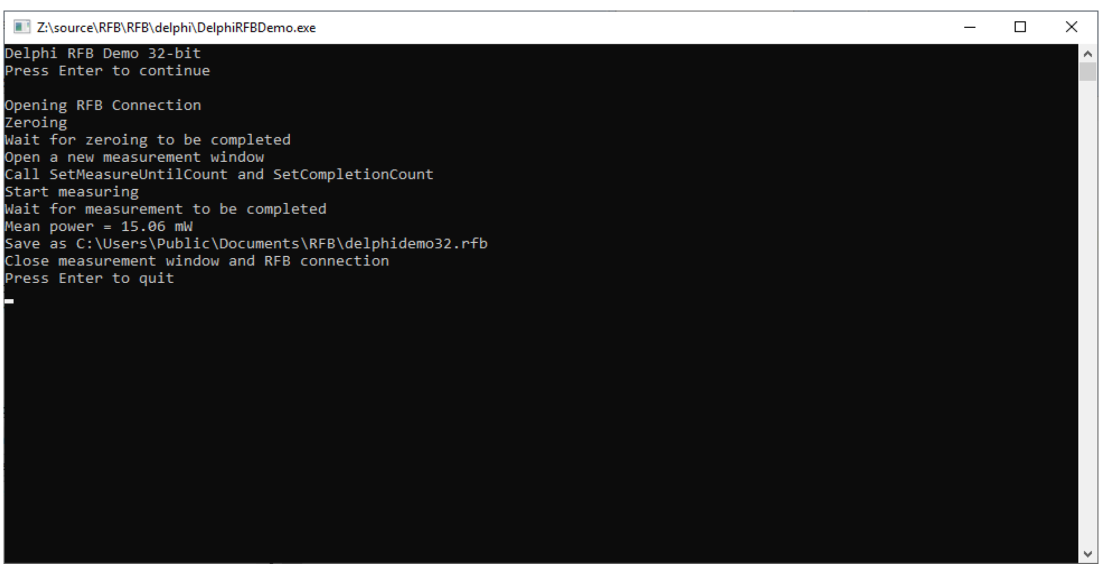
10.9.2 Delphi

Onda provides a simple demo program written using Delphi in two versions: DelphiRFBDemo32.exe (32-bit) and DelphiRFBDemo64.exe (64-bit) along with source files, DelphiRFBDemo32.dpr and DelphiRFBDemo64.dpr.

Before running the demo, the RFB software should be running. As in the case of the Matlab demo, this can be run either simulated or with the RFB hardware connected and working. When you run the demo, it executes these steps:

Check if the RFB software is running, exit if not
OpenRFBConnection, using 127.0.0.1 (this computer).
Zero
Enter a repeat..until loop, exiting when Zeroing returns false.
NewAutoMeasurement
SetMeasureUntilCount to true
SetCompletionCount to 10
StartMeas
Enter a repeat..until loop, exiting when Measuring returns false.
Display result from GetMean, multiplied by 1000 (to be in mW).
SaveAs C:\Users\Public\Documents\RFB\delphidemo32.rfb or delphidemo64.rfb
CloseMeasurement.
CloseRFBConnection.

This is what the demo (32-bit) looks like when completed:



Please note that this demo is provided on an as-is basis with no warranty. It has been built with Delphi 10 Seattle (as both 32- and 64-bit) and tested with RFB.exe 2.0.11.0. If you have any problems with the demo or the RFB-2000 software, please contact Onda.

11. Specifications

Acoustic Power Range	1 mW[*] to 2W with flat absorbing target Up to 20W with cone target Up to 100W with brush target
Display Resolution:	> 4 digits
Measurement Uncertainty	< 5% at 95% confidence [*]
Measurement Cycle Time	2 sec. ON, 2 sec. OFF minimums
Noise (Std. Dev.)	< 2 mW
Maximum Beam Diameter	5 cm
Low Frequency Limit	1 MHz (usable at lower frequency with decreased accuracy)
Target options	Flat absorptive, reflective cone, HIFU brush
Device Interface	
Logic	TTL (0-5V) compatible, active-high and active-low
DC	24V, 0.5ADC, fully-isolated C, NO, NC
RF	2 Watts max, 50-ohm terminated OFF Isolation > 45 dB @ 20 MHz
Computer	
Operating System	Windows XP-SP2, or Windows 7 32- or 64-bit, or Windows 10 64-bit
USB Interface	1.0 and 2.0 compatible
AC Power Requirements	90 - 264 VAC, 47 - 63 Hz
Physical	
Tank Dimensions	33.5 cm High x 21.5 cm O.D.
Tank Transducer Support	50 cm High
Tank Weight	7.5 Kg (max water filled)
Controller Dimensions	19 cm Wide x 7 cm High x 26 cm Deep
Controller Weight	1.6 Kg
USB Cable Length	2 m
Sensor Cable Length	2 m

[*] Extended averaging may be required, depending on local vibration

12. Measurement Example

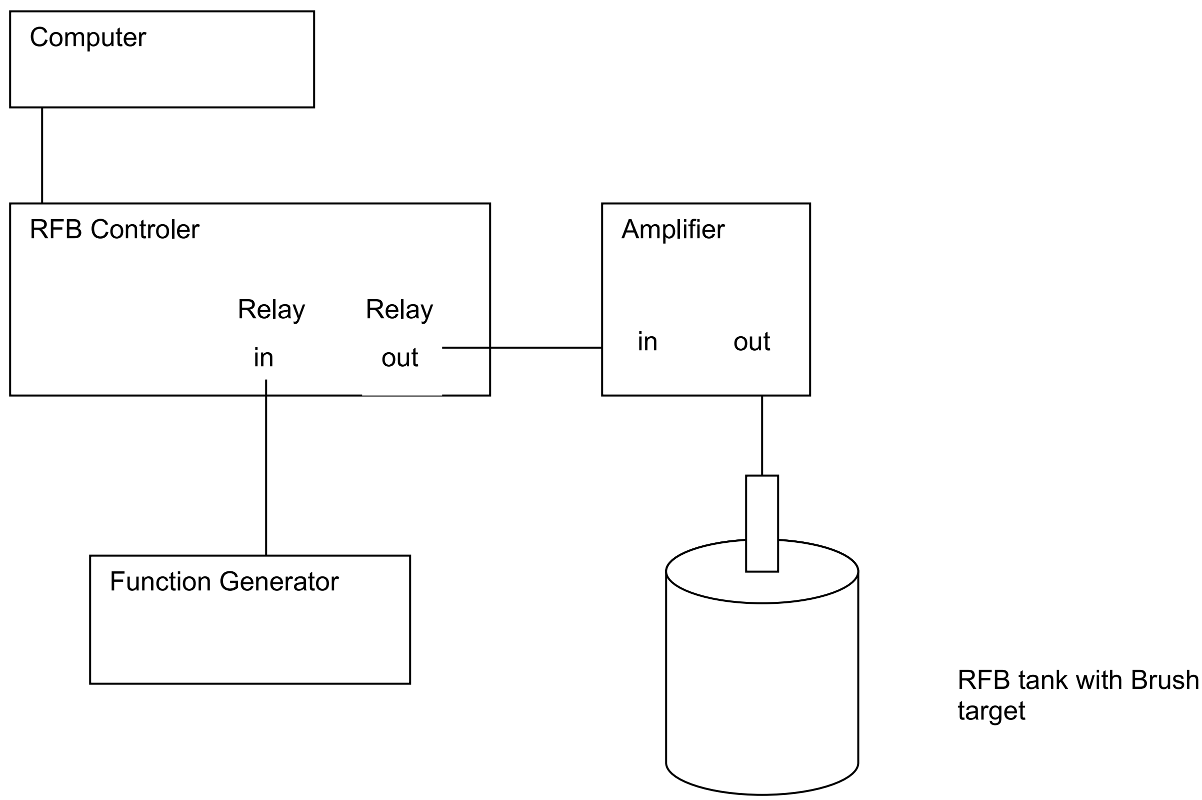


Figure 1.
Interface with Transducer Driving System

Figure 1 describes a typical measurement setup—in this case for a HIFU transducer. The output of the function generator is fed through the relay on the front of the RFB-2000 controller box, and the output of the relay is applied as input to the amplifier. This allows the RFB software to turn the sound power on and off automatically. Placing the relay between a function generator and power amplifier is recommended in those cases where the electrical power into the transducer is greater than the 2 Watt rating for the relay.; for lower input electrical power, the transducer may be connected directly to the relay. Alternatively, if the electronics generator can be triggered, the TTL output of the controller box could be used. Also, the DC relay on the controller can be used whenever the transducer's driving system can be controlled by a DC power supply.

The step sequence for a typical measurement is described below.

12.1 Setup

1) The sensor assembly is inserted into the tank. The water level is adjusted to be greater than 1 cm above the top of the target. Any bubbles stuck to the assembly are removed either by gently brushing them off, blowing them off with a jet of water from a syringe, or reaching into the tank, picking the assembly up while immersed, and shaking it (it is best to hold the assembly to constrain its motion in order to avoid it rattling around when shaking it).

2) If using the brush target, the target is degassed as described in Section A.III under "Theory of Operation." And inserted in the tank

3) It is generally good practice at this point to zero the force balance, to avoid being at an extreme of the range of motion of the assembly. Under the target-type icon, the target type is selected (this allows the appropriate servo parameters to be loaded, as well as records the target type in the results file).

12.2 Calibration

1) Calibration is selected from the software menu.

2) The user is then prompted to apply and remove the calibration mass. Onda provides a platform which rests on the target, allowing the mass to be applied in air.

The user can either repeat the measurement until satisfied with the 95% confidence interval of the measurements, preset the number of measurement cycles, or preset the desired 95% confidence interval and the calibration will iterate until that 95% confidence interval is reached.

3) Upon completion, or pressing of the "Stop" button, the program asks the user to press an "Apply" button. Once the "Apply" button is pressed, the new calibration factor is set in the program, and stored in the calibration log file so that this calibration factor will be used next time when the program is started.

12.3 Measurement

1) If necessary, water can now be added to the tank to bring it to the desired level.

2) The transducer is now positioned above the target. The distance is set so as to make sure the beam diameter is well-contained within the area of the target (see section A.III under "Theory of Operation"

3) "Automatic Measurement" is now selected from the Toolbar.

4) The program proceeds to turn the sound beam on and off. A measurement is made after each on/off cycle, and the mean of the measurements is updated after each measurement.

5) The user can either repeat the measurement until satisfied with the 95% confidence interval (1.96 * standard deviation of the mean) of the measurements, preset the number of measurement cycles, or preset the desired 95% confidence interval and the measurement will iterate until that 95% confidence interval is reached.

6) Upon completion or pressing the “Stop” button, the user can use the “File/Save As…” menu item to save the results to a file.

13. Troubleshooting Guide

In case of difficulty in making measurements, we suggest the following steps:

1) Make sure that the sensor is in the tank, resting squarely on the bottom (the base should be parallel with the bottom of the tank, resting on the three screws on the bottom of the base)

2) With water in the tank above the level of the sensor, and no target yet on top of the sensor, the can of the sensor should float to the top of its range. It should be possible to gently push the sensor float to the bottom of its range (1mm excursion) with your finger

3) Make sure that your target is in the tank, and that the water level is 15 - 25 mm above the target (note that if you are having problems they should try this with the standard "flat" blue target)

4) Is the tank free of foreign objects (debris, etc.)?

5) Is the sensor mechanism free of bubbles in its moving parts?

6) Is the controller on and are both ends of the cable to the tank connected? Is the controller connected to the computer? Also, did you check to make sure that there is no obvious damage to the cables, such as bent or recessed pins on the cable between the controller and the tank?

7) Check to make sure that the software is NOT in simulated mode

8) The software will now check the position sensor. User should watch to see if the sensor goes between the lower and upper stops

9) If check position sensor results are not good, check again to see if the sensor is seated properly. If it is, visually check the sensor to see if hinges are broken, and that the sensor can move just up and down without wobble

10) Check to see that the circle is running. It may be red because the system has not zeroed

11) The software should now be zeroing

12) If it is having trouble zeroing, turn zeroing off (recent versions of SW). See if the circle is running and red or green.

13) Check to see if the temperature is being displayed

14) When running mass cal, make sure that before you exit the calibration routine that you remove the stand and re-zero first, before closing the calibration window

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