Ultrasound power measurements of HITU transducer with a more stable radiation force balance

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Abstract. A new radiation force balance (RFB) system was established at Turkish National Metrology Institute (UME) Ultrasonics Laboratory for High intensity therapeutic ultrasound (HITU) power measurements. The new system is highly stable at high power levels up to 500 Watts. The measurement system consists of a Plexiglas cylindrical balance arm, target mounting scale disks, conical reflecting and absorbing targets, adjustment nuts, and a hanging wire. Both of the two sides of balance were mounted similar size and weight targets. The equilibrium of the balance arm can be adjusted with nuts on screws located at both sides of the balance arm. Transducer was mounted to bottom of water tank. Absorbers in the bottom and the near walls of the tank were used for reflecting target case. Ultrasound power was applied to one scale of the balance where the reflecting/absorbing target was mounted and corresponding force was measured on the other scale of balance where was connected to a balance with a thin wire while the thin rest standing on a support. Ultrasound power of two HITU transducers at frequencies 0.93 MHz, 1.1 MHz and 3.3 MHz were measured with conventional and new system, the values were compared and uncertainty components were assessed in this paper.

1. Introduction
Ultrasound power was measured with absorbing or reflecting target by conventional RFB described in IEC 61161 standard [1]. Instability of the target may cause errors in alignment of the target and mathematical calculations (Figure 1). For high powers above the 50 Watts, the rolling movement of the target under the effect of the transducer may be dominant error in ultrasonic power measurements (Figure 2).

Ultrasound power directly depends on the change in apparent weight of target, \( m \) exposed to ultrasound radiation, between the on and off times of input electrical power due to formula, \( P=mgc \). The other two parameters, \( g \) and \( c \) are acceleration of gravity and speed of sound correspondingly. \( g \) depends on geographical location and \( c \) depends on water temperature.

Therefore the change of apparent weight must be calculated as correct as possible.
Figure 1. Schematic view of the instability of the absorbing target exposed to high power ultrasound. Similar rolling is seen for the reflecting target as well.

Figure 2. Errors may occur at mathematical calculations due to instability of the curve.

In order to overcome this drawback, one method is to maintain the target at the bottom of tank. In this case a stable positioning system to mount the transducer is required. But as the HITU transducer is a bowl type transducer, air bubbles can easily be occur during montage (Figure 3 and 4). Removal of the bubbles is hard and time consuming task. The air bubbles also easily could be born due to the cavitation effect at high power applications.

New set up was designed and built at UME for stable measurements of HITU power. The set up enables to eliminate efficiently problems mentioned above.

Figure 3. HITU application is downward in RFB set up with absorbing target. Bubbles are occurred.

Figure 4. HITU application is downward in RFB set up with reflecting target. Bubbles are occurred.
2. Modified RFB set up
The stable RFB set up has been constructed at TÜBİTAK UME. New modified radiation force balance was used with reflecting and absorbing targets (Figure 5 and 6). Ultrasound power was applied to one scale of the balance where the reflecting target was mounted and corresponding force was measured on the other scale of balance where is connected to a balance with a thin wire, while the thin rest standing on a support. Transducer was mounted to a bottom of a water tank. Ultrasound radiation was applied upward to target. Absorbers in the bottom and the near walls of the tank were used for the reflecting target in use.

![Figure 5](image5.png)  
**Figure 5.** Schematic of the modified RFB set up. Note that an absorbing target can be mounted at the same set up.

![Figure 6](image6.png)  
**Figure 6.** View of the modified RFB set up with absorbing target

3. Measurement results
The determination of the apparent weight change in the new modified and stable set-up is better and it can be calculated with higher accuracy. This fact could be clearly seen from Figure 7. There is no fluctuation in power measurements in the modified RFB set up since it stands on a support. This gives opportunity to perform more stable power measurements.

![Figure 7](image7.png)  
**Figure 7.** Qualitative presentation of apparent weight change with the modified RFB set-up.
Three uncertainty components that are influence of mathematical procedures to calculate radiation force from balance read-out curve, transducer and target alignment and repeatability decreased as seen in Table 1. Total decrease in combined uncertainty is approximately 1.5%.

Table 1. Comparison of three uncertainty components. Note that the combined uncertainty covers all other uncertainty components.

| No | Uncertainty Component                                | Conventional RFB | Modified RFB |
|----|-------------------------------------------------------|-------------------|--------------|
| 1  | Influence of mathematical procedures to calculate radiation force | 0.58              | 0.14         |
| 2  | Transducer and target alignment                       | 2.22              | 1.73         |
| 3  | Repeatability                                         | 4.0               | 1.0          |
|    | Combined Uncertainty                                  | 6.95              | 5.50         |

4. Conclusion
In order to overcome the instability of power measurements of RFB set up for high power measurements, new modified set up were constructed at TÜBİTAK UME. In spite of the fact that expanded uncertainty with new set-up is a little bit higher than with conventional RFB, the overall performance of the set-up satisfies general requirements for high power ultrasound measurements. Approximately 1.5% total decrease in combined uncertainty was achieved.

However the ultrasound power measurements with reflecting target at the modified RFB, has good stability, it gives 10-15% higher radiation conductance values compared to RFB set ups with absorbing target and other set ups i.e. thermal methods. But ultrasound power measurements at the modified RFB set up with absorbing target gives comparable radiation conductance values compared to other methods [2]. For example, Sonic Concepts transducer whose radiatio conductance value is measured at the comparison (European Metrology Research Programme “External Beam Cancer Therapy” project comparison), measured again and same value was reached at the modified RFB set up with absorbing target.

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5. References
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