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STATISTICAL ANALYSIS OF DIFFERENT ABSORBING TARGETS FOR ULTRASONIC RADIATION FORCE MEASUREMENT

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Abstract: Ultrasonic power measurement in the megahertz frequency range is undertaken according to the physical principle of radiation force. In this case, a device named "radiation force balance" is habitually used for output powers lower than about 20 W. The construction of a radiation force balance presupposes the use of either a reflecting or an absorbing target. In this paper, it is detailed a statistical analysis of 5 different absorbing targets used in an implementation of a radiation force balance measurement device. The output frequency was 3.5 MHz, and two transducers (nominal diameter of 25.4 mm and 12.7 mm) were used at nominal output power of 10 mW, 100 mW and 1 W. The measured quantities were output power and conductance radiation. Using the standard error *En* as parameter, in for all output setup combinations (output power and transducer diameter) the results for both quantities were considered statistically identical ($En < 1.0$).

Keywords: ultrasound, power measurement, statistical analysis, absorbing target, metrology.

1. INTRODUCTION

Ultrasonic power is one of the most important parameter to qualify an ultrasonic device, particularly those equipment used in biological tissues (medical devices). The application of many technical standards demands the knowledge of the total output power in order to state the conformity accordingly to safety and essential performance [1][2]. In general, output ultrasonic power is measured using a radiation force balance as described in [3]. That standard suggests the use of a reflector or an absorbing target. In the case of an absorbing target, there is a rationale prescribing some ultrasonic characteristics: reflection factor < 3.5% and absorption > 99%. Even so, the whole system should be considered validated if all assembling parts are working properly as a whole set unit. The aim of the present work is to present a statistical analysis of power measurement of an ultrasonic source using 5 different absorbing targets used in a radiation force balance.

2. MATERIAL AND METHODS

The main measured parameter was ultrasonic power as described in [3].

2.1. Equipment and instrumentation

The ultrasonic source was a continuous wave check source (Precision Acoustics, UK) with nominal working frequency of 3.5 MHz. Two submersible ultrasonic transducers (Olympus NDT – Panametrics, USA) were assembled: 25.4 mm of nominal diameter (model A380S) and 12.7 mm (model A382S). The measuring device was a microbalance model CP224S (Sartorius, Germany) and some homemade specially designed assembly parts. Figure 1 shows a picture of the measuring system.

Fig. 1. Ultrasonic power measurement device: continuous wave check source, 3.5 MHz transducers, microbalance and assembly parts (no target is present).

2.2. Experimental procedure

Measuring parameters were output power and conductance radiation. Despite both are important for a complete setup validation, as they are close related to each other, for simplicity only the output power will be discussed in details.

Power measurements were done accordingly to prescriptions in [3]. In total, 4 measurements in repeatability conditions were performed for each target and at 3 different output nominal powers: 10 mW, 100 mW and 1 W.

For each repetition, the source was turned on and off 5 times, and the difference between the OFF to ON mass reading was computed. The transducers were settled in 3 different distances from the target surface in order to calculate the output power on the transducer surface by linear regression of data.

2.3. Targets

The target were rubber like material commercially available from Precision Acoustics (UK). They were either in pyramidal shape or flat surface, and presented square (100 mm large) or circular shape (30 mm of diameter).

2.4. Statistical analysis

For each output power, the setup with each target was considered as a weakly correlated measurement instrument. So, the standard error E_N was used as comparison parameter:

$$E_N = \frac{\overline{P} - P_i}{\sqrt{U_{\overline{P}} - U_i}}, \qquad (1)$$

where $\overline{P}$ is the average power for the 5 different targets, P_i is the power assessed using each one of the 5 targets, $U_{\overline{P}}$ is the combine expanded uncertainty and U_i is the expanded uncertainty for obtained with each target.

3. RESULTS

In Table 1, all results are depicted. The transducer is identified in the first column (Tx). The second column are disclosed the nominal output powers (P, in mW). The third column are the results entries for the power (P) and the overall expanded uncertainty (in %, p > 0.95). The following columns are the results for each different target (T1 to T5).

Tx	Nominal P [mW]	Results	T1	T2	T3	T4	T5
A380S 25.4 mm	10	P [mW]	10.69	9.88	10.48	10.70	10.26
		Unc [%]	4.3	4.8	4.4	4.7	4.6
	100	P [mW]	133.4	128.9	131.8	132.9	132.5
		Unc [%]	1.2	1.2	1.2	1.2	1.2
	1000	P [mW]	978	955	965	971	983
		Unc [%]	1.2	1.2	1.2	1.1	1.2
A382S 12.7 mm	10	P [mW]	11.10	10.47	10.82	11.08	10.68
		Unc [%]	4.1	4.3	4.3	4.3	4.2
	100	P [mW]	136.8	134.0	136.4	136.4	136.4
		Unc [%]	1.2	1.2	1.2	1.2	1.2
	1000	P [mW]	1454	1427	1427	1433	1453
		Unc [%]	1.2	1.1	1.2	112	1.3

4. DISCUSSION AND CONCLUSION

In all cases, the standard error is less than 1. In a simple and straightforward analysis, the use of any of the absorber targets would lead to equal results, having the uncertainty as a comparison basis. Further than the simple evaluation of the ultrasonic absorption and insertion loss, the analysis of a set of power measurements are more likely to confirm the metrological equality of different assemblies of a given device or measurement system.

As a final conclusion, all targets evaluated in the present study could be considered statistically equal, so the use of either of them would not jeopardize the metrological reliability of the results.

5. REFERENCES

[1] IEC 60601-2-37 Ed. 2.0, *"Medical electrical equipment – Part 2-37:Particular requirements for the basic safety and essential performance of ultrasonic medical diagnostic and monitoring equipment"*, International Electrotechnical Commission, 2007.

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