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THE BRAZILIAN NATIONAL LABORATORY OF ULTRASOUND

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Abstract: Aiming to support the national metrology on ultrasound, Inmetro, the Brazilian National Institute of Metrology (NMI), has been putting effort on its Laboratory of Ultrasound (Labus). In a first approach, Labus is able to offer traceability in basically four general areas: Ultrasonic (US) Transducer Calibration, US Power Measurement, US Field Mapping, and Reference Materials Certification for US applications. The frequency range Labus firstly established its calibration and testing methods is from 0.5 MHz to 20 MHz, being the limits dependent on the particular application considered. So far, Labus most important facilities consist in two water tanks, three manuals and one complete remote-controlled micro-positioning systems, three equipments sets to generate and acquire US signals (arbitrary waveform generators and scopes-like instruments), a set of transducers and primary standards in Power Measurement (a stable US power source) and Hydrophone Calibration (two membrane hydrophones). For while, Labus is traced to others NMI, but the goal is to implement absolute calibration methods in two years time. Within this paper, Labus will be presented in details, particularly outlining its state of art in Transducer Calibration, Power Measurement, and Reference Materials Certification. Join ventures with industry and private and universities laboratories will be outlined, either.

Keywords: ultrasound, transducer calibration, ultrasonic power measurement.

1. INTRODUCTION

Despite the spread use of ultrasound in Brasil, both for industrial and health care applications, costumers could not count on a national laboratory on ultrasound. That lack on Brazilian traceability system was observed, and Inmetro, Brazilian National Institute of Metrology (NMI) has been working on it since 2001, aware of its very important institutional mission. After a research with actual and potential users in ultrasound field, which consisted basically in on-site interviews and by-wire or Internet information collection, the main work guidelines for the Laboratory of Ultrasound (Labus) at Inmetro had been defined. As a primary business and research opportunity area to attach, ultrasound (US) for health applications was chosen. US applications embrace, but do not is limited to, physiotherapy treatment and medical imaging diagnostics (ultrasonography). A consistent laboratory infrastructure is necessary to cover that area, and a high level staff is a basic demand, as well. The fist two years of Labus' focused laboratory implementation program, which was planned to last for 6 years, have been fundamentally directed to establish both the infrastructure and the working staff.

The goals have been achieved, and presently Labus has three calibration and testing services available: Absolute Transducer Calibration, US Power Measurement, and US Field Mapping.

A forth Labus attribution is to support and provide Reference Materials Certificates (RMC) for industrial and laboratorial applications. A 3-year program in this field was planned, and its execution has been done as planned. In two years time, at least 4 RMC will be available for national (and international) costumers.

University and industry laboratories have been kept as close as possible, basically with development projects (regarding industry) and scientific and academic research with university. A doctoral and two master degree theses were finished, and a third one is on course. With industry and/or private engineers, two materials certification program are running, and a US power source is being developed. With this attitude, three pillars of a sustainable development program, based in metrology, are kept in mind: scientific research, industrial development, and improvement of customers (citizens) quality of life, the last one being a final goal, as well.

This paper will present Labus state of art, as well as its future development planned up to the end of the preparation of this manuscript.

2. PURPOSE

As basic and initial approach, ultrasound applications for which Labus shall be prepared to support, in a long time base, are as following:

Biomedicine

Physiotherapy treatment: As a national law demand, all physiotherapy equipment sold in Brasil shall be tested accordingly to IEC 60.601-2-5 [1], if there was a national accredited laboratory. Despite there are 4 laboratories accredited for medical equipments safety testing, no one is fully able to test ultrasound equipment, mainly because there

is no national traceability system. Labus is working to change that situation.

Medical imaging diagnostic: Similarly to physiotherapy equipment, medical imaging instruments using ultrasound to interrogate biological tissue cannot be tested for any accredited national laboratory. Traceability is also a cutting edge on that issue.

Other applications Labus will be able to offer traceability, but are not on priority level, are blood flow, lithotripsy (kidney stone treatment), and biomicroscopy (nanometre scale imaging).

Industrial field

It is neither a first priority for Labus, but is a natural way to be prepared to support to those applications, as long as they are quite usual in industry and similar, particularly for oil and gas. Non-destructive testing (welding and metal materials quality assurance), oil and gas duct flow measurement, and cracking monitoring of pressure vessels are some examples for US applications Labus could support in a not far future.

Those are not but a tinny list of ultrasound applications, but, due restrictions of staff number, financial support, and physical spaces for facilities, they were initially chosen to Labus work with. Further, as observed demand improves in other areas, the list of services may be increased.

3. METHODS

Labus has been implemented together with a detailed outsourcing of national actual and potential necessities. To accomplish with the depicted goals, financial support and staff contracting and training are of first priority. Part of Labus budget has been cleared from the Division of Acoustics and Vibration Metrology (Diavi) and de Directory of Scientific and Industrial Metrology (Dimci), from Inmetro.

Another way of money outsourcing largely used has been through projects submit to national agencies with public and/or private funds. Labus was awarded with a 4-years scholarship program from the Brazilian National Council for Scientific and Technological Development (CNPq), which consists in budget enough to the commitment of two guest research scientists. Presently, those two guest scientists are running projects in US Field Mapping and US Power Measurement, both parts of Labus implementation program.

A 6-year project was planned in 2004 to fully establish Labus. Despite some eventual unexpected drawbacks found out during one few activities, the mains lines of the plan are on their right way.

The fully establishment of a high level Metrology Laboratory should include research and development. From this point of view, collaboration with industry and university is included in the implementation program. Labus staff is encouraged to continued discussion, visits, and information exchanges in appropriated forums. Those pro-active actions gave the bases for at least 5 join ventures with industry and university.

4. RESULTS

As a consequence of the Methods used to establish Labus, some results were achieved so far. They will be presented under this Section, divided accordingly to the four main areas referred to in the Introduction. In a fifth sub-section, some results regarding external collaboration will be depicted.

4.1. Absolute transducer calibration

As basic equipment in every metrological application in ultrasound, transducer calibration is a fundamental necessity. Because of that, the first calibration service provided by Labus was that one. The chosen method was "Reciprocity", an absolute one well defined for a long time. An acrylic-walled water tank (1000mm × 250mm × 250mm), two manual micrometer positioning system, and a stainless steel cylindrical reflector (∅ = 58mm; 78mm long) were developed by Inmetro's precision mechanic workplace (see figure 1 and 2). The method was validated against calibrated membrane hydrophones, Labus primary standards, traced to National Physical Laboratory (NPL, Teddington, UK). The method was developed accordingly to [2].

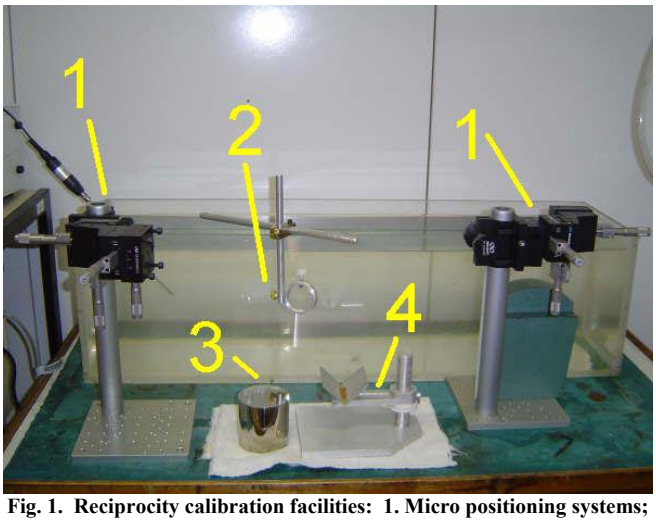

Fig. 1. Reciprocity calibration facilities: 1. Micro positioning systems; 2. Transducers holder; 3. Stainless steel reflector target; 4. Target bed. The acrylic water tank is in the figure background.

Fig. 2. Stainless steel target and its bed in detail.

A paper describing the first research work using that implementation is to be published in a National Congress on Biomedical Engineering [3]. Basically, they were tested two transducers: a model A304S (GE Panametrics, General Electric Company, Fairfield, CT, USA), with ∅ = 25.4mm and nominal frequency of 2.25 MHz, and another used for physiotherapy treatments. Results point out to values of relative error less than 10%. Sensitivities of both transducers are linear within the their frequency bandwidth for voltage ranging from 0,5 to 18 Vpp. In a further step, the results were compared with measurements undertaken with Labus hydrophone standards, and the sensitivity curves were identical within calibration uncertainty (less than ±1.5 dB).

Bilateral interlaboratorial comparison are planned to take place in 2007, after which the calibration service will be able to claim inclusion at *Bureau International de Poids et Measures* (BIPM) NMI's service list.

4.2. Ultrasonic power measurement

The most spread calibration technique in Brazil, in the ultrasound field, is power measurement, once many laboratories have a radiation force balance in their facilities. Because of that, one of Labus priorities was primary ultrasonic power measurement. The method was developed accordingly to [4]. The system was home made, using as basic equipment a 4-digit (0.1 mg) precision microbalance. The validation of the method was done against an ultrasonic check source, working at 3 MHz and 10 mW, 100 mW or 1 W of output power. Labus' system has uncertainty of no more than 4 mW, and a resolution of 2 mW. Details of the procedure for US Power Measurement implementations can be find in an accompanying paper, to be published in this conference [5].

4.3. Ultrasound field mapping

The acoustic pressure field mapping system owned by Labus had been implemented, based on Standard IEC-61102 [6]. That system will be capable to estimate ultrasound pressure field parameters from biomedical transducers, an essential step to calibration and certification of ultrasound equipments. Data acquisition is carried out on a water bath, with a positioning system moving either a hydrophone or a transducer. Usual experimental set up consists in a hydrophone generating electrical signals in response to transducer's waterborne acoustic signals, captured over its acoustic field. Transducer and hydrophone positioning is fully remote-controlled through a homemade software. Details of the procedure for US Power Measurement implementations can be found in an accompanying paper, to be published in this conference [7].

The main use of the US Field Mapping system is to test medical US transducer output, both for performance and safety inference.

4.4. Reference Material Certificates

For the 3-years plan established in 2005, Labus took the responsibility of offering 4 new RMC, basically to provide national traceability and to improve the Brazilian industry. Those RMC are listed bellow:

V1 and V2 standard blocks for Non Destructive Testing

A join venture with a national manufacturer was initiated in June 2006. The first blocks will be tested during 2006, and, accordingly to the results, Inmetro will provide a Certification on dimensional and ultrasonic characteristics of those blocks. The Certificate will assure compliance to [8] for block V1 and to [9] for block V2. Prevision to offer that RMC to internal and external market is February 2007.

Ultrasonic absorbing material

A rubber-like pad with high US absorbing capability is under development. A new staff member or an external professional with background on Chemistry is to be contracted to conclude the project already in course. To develop that material, Inmetro's Division of Chemistry Metrology will be involved, particularly in chemical analysis and solution preparation. As a goal, the material should absorb over 99% of incident US energy, basically to assure compliance to Power Measurement tank absorbing lining accordingly to [4] (98% or more – see [5]). Prevision to offer that RMC is May 2007.

Standard insulation material

Glycerine-based solution in water, with different composition, will be developed and, most important, tested to certify their US attenuation. The project to develop this standard attenuator had not been initiated so far, but it is scheduled to start the study by November 2006. One year is the prevision to conclude the project and offer the RMC to customers.

Phantoms for diagnostic, simulating biological tissue

The most difficult, but with an expressive demand, RMC is biological phantom. This product is used as a mimetic of biological tissues, simulating, for instance, heating and perfusion characteristics of animal organs. The degradative nature of material usually employed in biological phantoms imposes a challenge to metrology, once long-term stability is a most unlikely, despite necessary, characteristic. In spite of that drawback, development will begin no later than May 2007, and it is planned to last no more than one year.

Depending on future demand, other RMC may be included, accordingly to industrial and laboratorial necessities.

4.5. Research and development in cooperation with university

Concerning technical and scientific production, until the end of 2005, they were published 8 papers in international congresses and symposiums, plus 5 in national forums. For 2006, Labus staff produced two papers in scientific journals (other 3 are under development), 6 papers in national congresses, plus 8 in international meetings, at least.

They were developed 5 softwares for simulation and measurement automation, and 10 seminars and lectures were presented in universities, meetings and at Inmetro. One doctoral and two master degree theses had been concluded

with direct use of Labus facilities, and there is another master degree thesis under development.

To be outlined, the use of a special designed chirp-coded ultrasound excitation signal, called CEP-AMag, was used to improve both signal to noise ration and special resolution of a pulse-eco experimental set-up. Details can be found in [10]. As a remarkable result, the spatial resolution, calculated from the compressed pulse envelope, was around 1.02 μs when generated with linear excitation and 0.77 μs when using arbitrary excitation in the generation and the pulse compression by cross-correlation. The improvement in the spatial resolution was statistically significant ($p < 0.001$ after a pared t-test), what pointed the non-linear coded excitation as a promising signal for ultrasound imaging, if compared to other usual excitations.

That huge scientific production is due the close interaction between Labus and universities in Brazil. Following successful examples that are to be concluded, other joint projects will be planned and executed.

5. CONCLUSION

Inmetro's Laboratory of Ultrasound is already implemented and is operative. However, a huge effort is yet to be put to fully establish Labus. The expectative is that effort will shortly improve the quality of live of the population as a whole. Particularly, the metrology laboratories in Brazil got the clearest benefits. As a natural consequence, further collaborations are under consideration, and, as much as possible, those will lead to projects of national and international interest soon.

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