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CHANGES IN FIELD DISTRIBUTION FOR PHYSIOTHERAPY SYSTEMS WHEN IN CONTACT WITH SKIN MIMICS COMPARED TO THE FREE-FIELD DISTRIBUTION

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ABSTRACT

Measurements have been done on three physiotherapy transducers, two operating at 1 MHz, and the other at 3 MHz. Three skin mimics with thicknesses of 0,5 mm, 1 mm and 1,5 mm, respectively, have been used. Four set of measurements have been carried out for each transducer-skin mimic combination: free field; contact; non-contact close distance (< 1mm); non-contact longer distance (> 2mm).

There have not been found evidences of relevant changes in the field distribution of any of physiotherapy transducer tested when in contact with skin mimics in comparison with the free-field distribution.

RESUMEN

Se han realizado mediciones con tres transductores de fisioterapia, dos funcionando a 1 MHz y otro a 3 MHz. Se han utilizado tres simuladores de piel con espesores de 0,5 mm, 1 mm y 1,5 mm, respectivamente. Se han realizado cuatro series de mediciones para cada combinación transductor - simulador de piel: campo libre, contacto, no-contacto corta distancia (< 1mm); no-contacto mayor distancia (> 2mm).

No se han encontrado evidencias de cambios relevantes en la distribución del campo de los transductores ensayados cuando se hallaban en contacto con los simuladores de piel en comparación con la distribución de campo libre.

1 INTRODUCTION

Within the recently completed JRP of the EMRP Dosimetry for Ultrasound Therapy (DUTy) [1], the aim of one of its work packages (Application to clinical treatment (WP6)) was to provide a direct link between the methods developed in other WPs and the clinical use of therapeutic ultrasound with the long-term aim of improving treatment planning. The task 6.2 had the aim of developing and evaluating a treatment planning protocol by combining clinical data from real patients at one of the participant institutes, obtained by MRI, CT and ultrasound, with the transducer characterization and modelling methods developed in other WPs.

It is well known that the physiotherapy systems typically have resonant transducers which can be sensitive to the acoustic load presented by the medium into which they radiate. It is also known that the power radiated changes with the thickness of the coupling gel layer and that the presence of membranes that can cause back reflections may affect not only to the radiated power but to the resonance frequency as well [2, 3]. An interesting question is whether the presence of these membranes, and specifically the skin, also affects the radiation pattern. In others words, whether the acoustic field radiated through skin is different from the acoustic field radiated directly into water, and whether it is also sensitive to gel thickness.

It was the responsibility of CSIC, through its Laboratory of Medical Ultrasound Metrology (LMUM), to evaluate the changes in the field distribution of physiotherapy systems when in contact with skin or skin mimics. This paper summarizes the results of such evaluation.

2 MEASUREMENT ELEMENTS AND SET-UP

To carry out the evaluation of the changes in the field distribution for physiotherapy transducers when in contact with skin or skin mimics, measurements have been made in the water tank of the LMUM. All measurements and associated calculations have been done in accordance with IEC 61689 [4, 5, 6].

2.1 Measurement Elements

2.1.1 Skin mimics

There have been used three NPL of the following thicknesses: 0,5 mm, 1 mm and 1,5 mm respectively. All of them have a similar diameter of about 105 mm.

2.1.2 Physiotherapy systems

There have been tested three physiotherapy systems composed of a signal generator, HP 3336C, a power amplifier, AR 75A250, and the following check sources, similar to physiotherapy transducers, produced at the TNO [7, 8]:

- TNO-CS G101: S= 5 cm^2; f_r = 1,008 MHz
- TNO-TUI 609 : S = 5 cm^2; f_r = 1,0023 MHz
- TNO-CS G301: S = 5 cm^2, f_r = 3,0025 MHz

2.1.2 Measuring and data acquisition system

The pressure measurements have been done with a calibrated set composed of a needle hydrophone, Dapco2, and a FET preamplifier, Tektronix P6201 FET probe, 50 Ω.

The hydrophone has been displaced to the required locations in the water by means of the computer controlled positioning system of the beam plot system installed in the water tank of the LMUM.

A fast digital oscilloscope, Tektronix TDS 3052C, 500 MHz, 5 Gs/s, has been used to acquire the pressure data that afterwards were transmitted via LAN to a computer for processing.

a) NPL skin mimics **b) TNO check sources**

Figure 2: Measuring elements

2.2 Measurement Conditions

2.2.1 Input voltages

The following input voltages (peak to peak) have been used to feed the check sources:

- 14 v(PP) for TNO-CS G1011 and TNO-TUI 609;
- 14 V (pp) – 24 V (pp) for TNO-CS G301.

2.2.2 Skin mimic positions

3 separations between the transducers emitting surfaces and the skin mimics have been used:

- 0 mm, i. e. direct contact;
- 1 mm; and
- 2 mm – 4 mm.

2.2.3 Environmental conditions

All the measurements have been made in water under the following ranges of environmental conditions:

- Water temperature: 21 °C – 22 °C ;
- Air temperature: 22 °C – 25 °C mm; and
  Relative Humidity: 40 % - 45 %

3 EXPERIMENTAL RESULTS

3.1 Measurement Procedure

3.1.1 Measurement preparation

As it can be seen in figure 3, the skin mimics have been placed in position by means of a holder in such a way that the mimic faces were parallel to the transducer surface and that this were placed at the centre of the membrane. Before this, care had been taken to achieve that the radiating surface of the transducer were parallel to the water surface.

The distance adjustment between the transducer and the membrane surfaces has been done out of the water. Once the right adjustment had been achieved, the holder was carefully removed by rotation to one side of the transducer, far from it and from the hydrophone, placed at the other side of the transducer.

After this, all the three elements have been slowly immersed into the water. Once the desired depth of the transducer surface had been reached, time was allowed for stabilization. Care has been taken to remove any bubble that could have been formed below the transducer surface and on the two faces of the mimic membrane. Once there was certainty that all air bubbles had been removed, a mirror has been used for this purpose, the holder was placed in position by gentle rotation, when required.

3.1.2 Measurement protocol

The pressure measurements begun once enough time had been allowed for stabilization after the water immersion. The measurement process followed has been a simplified version of the procedure described in IEC 61689 for the characterization of the acoustic field produced by physiotherapy transducers. Thus, series of perpendicular line scans, namely x-scan and y-scan, have been made on planes perpendicular to the transducer axis at different distances to identify the acoustic radiation axis of the beam emitted by the transducer. When carrying out the line scans, care has been taken in choosing a suited resolution and total length not to miss any relevant feature of the beam shape. Once two points belonging to the acoustic axis had been located, thanks to the identification of the x- and y-scans maxima or minima, as the case could be, an L scan has been conducted to find out the beam axial pressure distribution of the transducers.

Figure 3. Partial view of the measurement set-up

Maxima and minima have been identified on the pressure axial distribution, and line scans have been taken in planes perpendicular at the beam axis at these points locations to find out the relevant beam profiles.

For each of the chosen separation distances between the transducer surface and the membrane, the whole process has been carried out for the two conditions, “free-field”, that is without membrane, and “disturbed”, that is, with the membrane placed. The series of measurements have been repeated several times and the order has been changed, sometimes beginning with the free-field condition and others with the “disturbed” condition.

3.2 Results at 1 MHZ

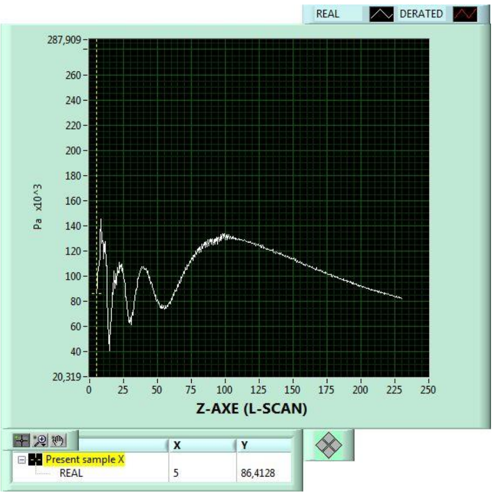
Due to space limitations it is impossible to show a complete set of the results obtained. Therefore only some results corresponding to TNO-CS G101 are presented in figure 4. The results showed correspond to the situation in which the membranes were in contact with the surface of the emitting transducer. However, the results obtained for the other separations and for the other transducer have been entirely analogous.

From the analysis of the obtained beam axial pressure distributions, the L scans, it could be seen that there was not any relevant different in the shapes of the axial profiles between the free field situation and those with each of the three membranes. The only differences seemed to be in the values of the pressure maxima.

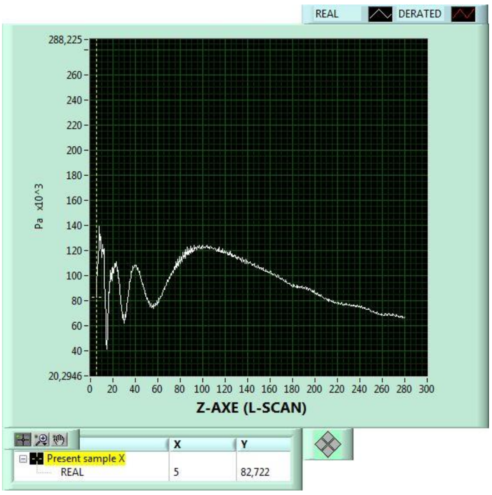
This impression was confirmed when the perpendicular line beam profiles, x and y, were carried out at relevant positions along the beam axial pressure distribution. From the study of these profiles, it could be concluded that there were no relevant changes in the profile shapes corresponding to the four situations, that is, free-field emission, and the transmission through membranes with thickness of 0,5 mm, 1 mm and 1,5 mm respectively.

As it regards the amplitude of the maxima, there was a small amplitude reduction as the thickness of the membrane increased that seems to be compatible with the absorption caused by the interposed membranes.

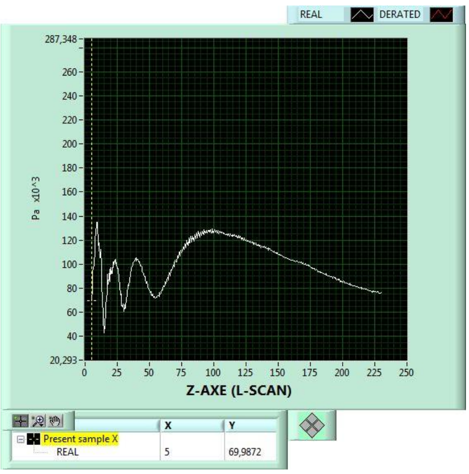
Beam axial pressure distributions



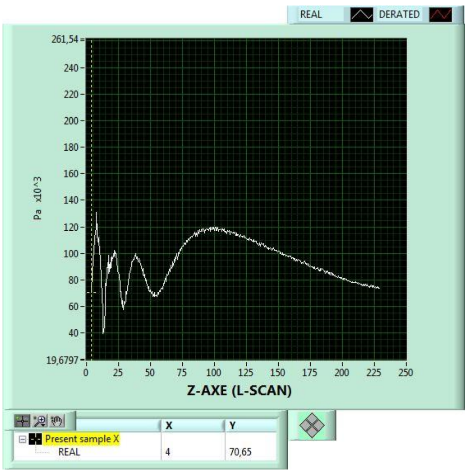
a) Free-field



b) 0,5 mm membrane



c) 1 mm membrane



d) 1,5 mm membrane

Figure 4: Beam axial pressure distribution of TNO-CS G101 (1 MHz) for different couplings

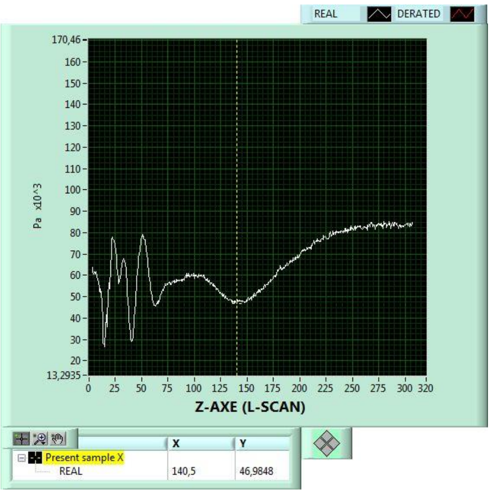
3.3 Results at 3 MHz

A selection of the results corresponding to TNO-CS G301 is presented in figures 5 and 6.

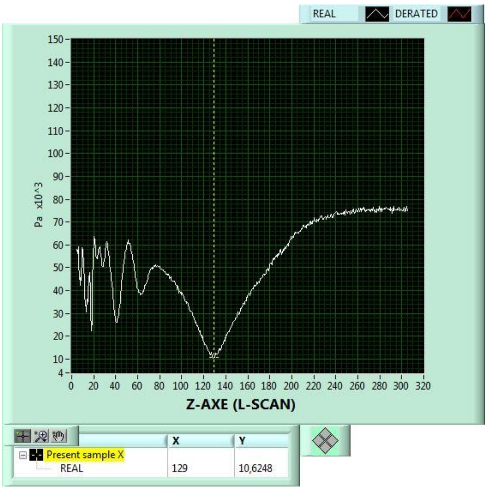
The results presented correspond to the situation in which the membranes were in contact with the surface of the emitting transducer. However, the results obtained for the other separations have been entirely analogous.

Although the radiation beam profiles at 3 MHz are much more complicated than at 1 MHz, from the analysis of the obtained beam axial pressure distributions, the L scans, it could also be seen that there were not great relevant differences in the shapes of the axial profiles between the free field situation and those with each of the three membranes, with the exception of a big fall corresponding to the case with the 0,5 mm membrane. As in the 1 MHz case, the main differences seemed to be in the values of the pressure maxima.

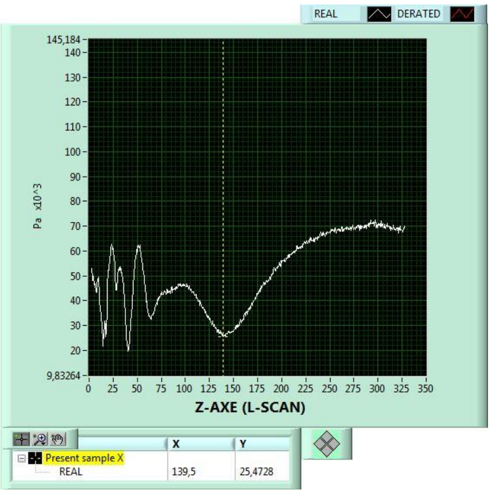
Beam axial pressure distributions



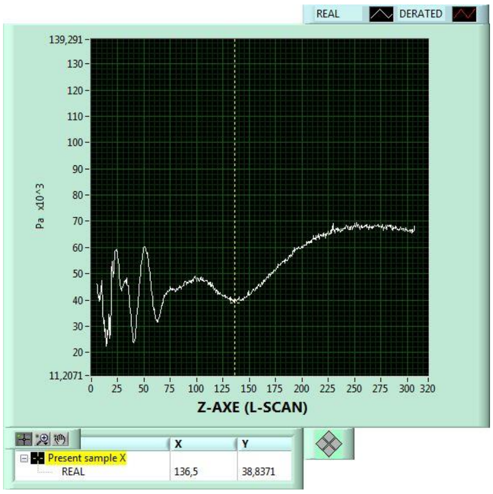
b) Free-field



b) 0,5 mm membrane



d) 1 mm membrane

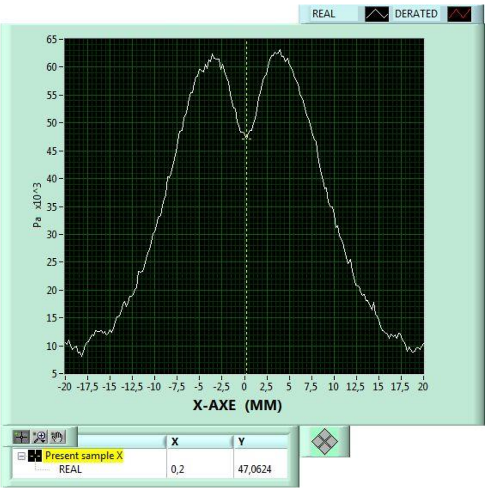


d) 1,5 mm membrane

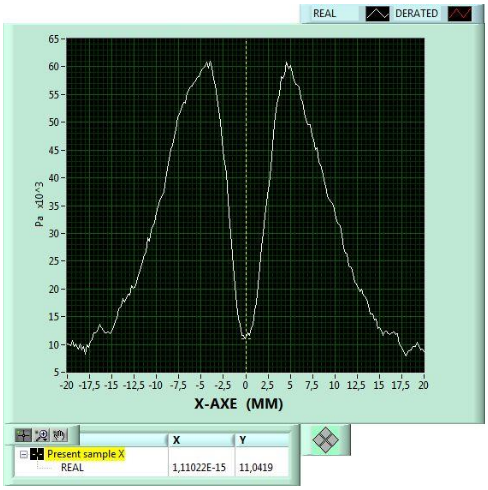
Figure 5: Beam axial pressure distribution of TNO-CS G301 (3 MHz) for different couplings

This impression was confirmed when the two perpendicular line beam profiles, x and y, were carried out at relevant positions along the beam axial pressure distribution. From the study of these profiles, it could be concluded that, leaving apart the case of the main minimum, there were no relevant changes in the profile shapes corresponding to the four situations, that is, “free-field” emission, and the transmission through membranes with thickness of 0,5 mm, 1 mm and 1,5 mm respectively.

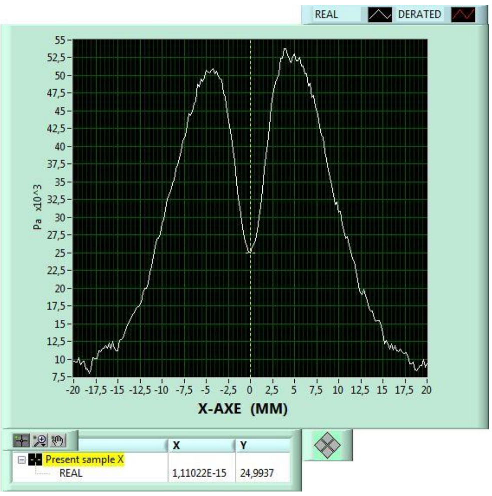
Beam profiles (x-scan) at main minimum (z ~ 140 mm)



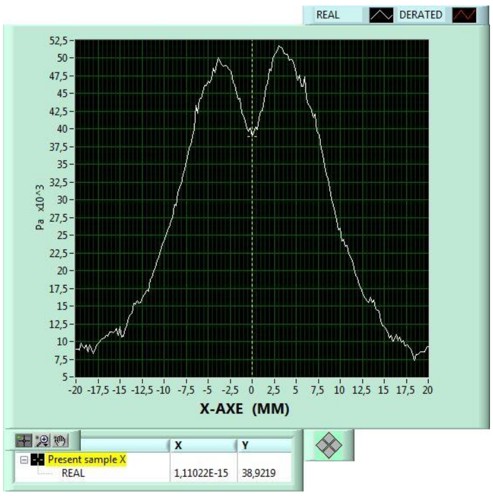
c) Free-field



b) 0,5 mm membrane



e) 1 mm membrane



d) 1,5 mm membrane

Figure 6: Beam profiles (x-scan) at main minimum (z ~ 140 mm) of TNO-CS G301 (3 MHz) for different couplings

As it regards the amplitude of the maxima, there was a small amplitude reduction as the thickness of the membrane increased that seems to be compatible with the absorption caused by the interposed membranes.

The case of the main minimum with a great fall for the 0,5 mm membrane, which recovers as the membrane thickness increases, it is probably linked to changes in the diffraction pattern due to the relation between the membrane thickness and the wavelength both in water and in the own membrane, though this issue should be investigated further.

4 CONCLUSIONS

There has not been found evidence of relevant changes in the field distribution of the physiotherapy transducers studied, in comparison with the free field distribution, when in contact with skin mimics.

In spite of having carried out hundreds of measurements, having used three different systems, operating at two frequencies, 1 MHz and 3 MHz, altogether with membranes of three different thicknesses, only minor amplitude changes, compatible with absorption in the membranes, and a case of possible diffraction pattern modification, have been found.

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