# 3-DIMENSIONAL IMAGING OF REFRACTORY MATERIAL AT PILKINGTON HALMSTAD


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**Centre for Imaging Sciences and Technologies**



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## INTRODUCTION

The Centre for Imaging Sciences and Technologies (CIST) at the University of Halmstad started in 1995 a new development to investigate and develop mulit-dimensional imaging for industrial applications. This development is generally referred to as Industrial Tomography. The technical development is mainly aimed at using radio wave interferometry (RWI) to do 3-dimensional imaging of slag-and metal bath surfaces in metallurgic processes. A number of collaborative projects are in progress with e.g. British Steel, LKAB, Boliden and other process industries in iron, steel, and metal. Contact was taken with Pilkington Halmstad in the autumn of 1995 in order to discuss related problems and possible collaboration with the glass process industry. During this discussion the problem of a continous and noninvasive measurement of the thickness of the refractory material during the ongoing process was raised. It was decided to make a preliminary experiment on a single ceramic plate as a test and demonstartion of the technique. Such a test experiment has now been performed at CIST.

## TEST PROCEDURE

The brick measured 60 x 50 cm and was measured to be 77-80 mm thick with a slight bulge at the center. The brick was mounted horisontally flat on a trolley and with support only at the outer edges. The central 50 x 40 cm of the brick was free from any underlying materia.

The trolley was passed under the sensor of the RWI system and measurements were taken on each part of a 12 x 10 grid, spacings 5 cm, over the surface. Two distinct peaks in the RWI signal could be clearly detected at each grid point, one peak corresponding to the radio wave entering the ceramic material in the brick and one peak corresponding to the signal exiting the ceramic material into air. Figure 1 below shows a typical such measurement at a gridpoint. An automatic procedure was then created to fit the response of these two peaks. The distance between these two peaks had a mean value of 240 mm. This corresponds to the optical distance between the upper and lower level of the brick. To get the geometric thickness of the brick one has to compensate the measured, optical distance for the slower speed of light in the ceramic material. The speed of light in the ceramic was decided from the geometrical measurements to be 80/240 = 1/3 times the speed of light in air, i.e. the refractive index of the ceramic material in the brick is $n \approx 3$.

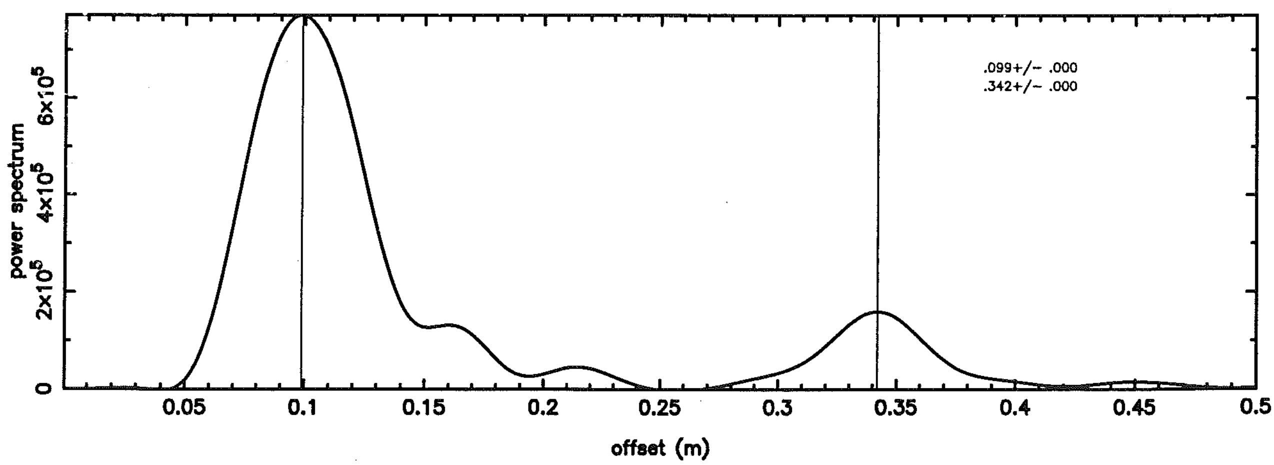


Figure 1. A typical response of the RWI system to the upper and lower level of the brick.

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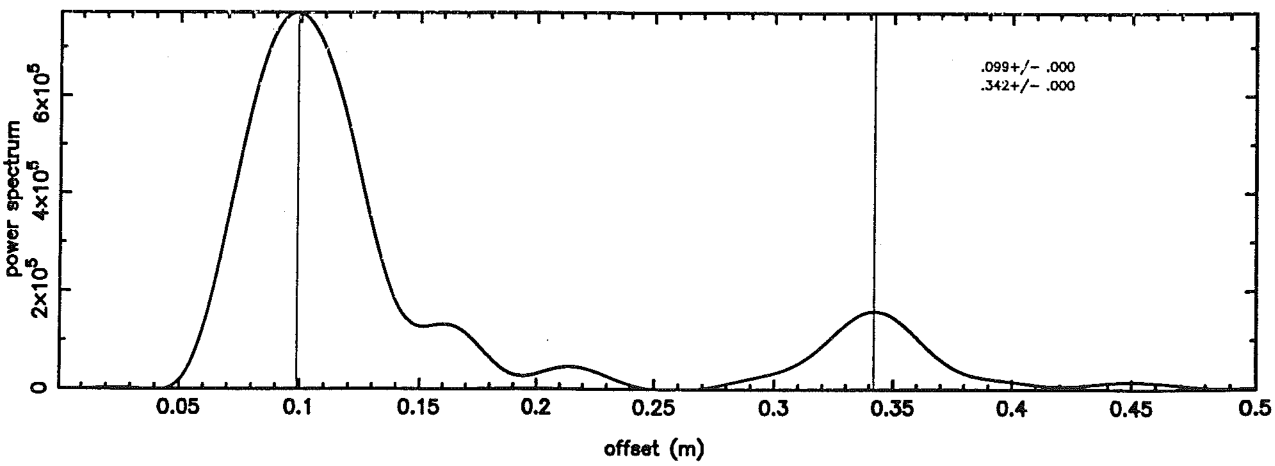


Figure 1. A typical response of the RWI system to the upper and lower level of the brick.

## MEASUREMENTS

The measured data are shown in Figures 2 and 3 below. The x and y coordinates refer to one of the corners of the brick. Both surfaces show that the brick had a small inclination to the horisontal plane. The lower surface also shows clearly that the brick is somewhat thicker in the middle than at the borders. The positions shown for the lower surface is the measured, optical position and has to be divided by the refractive index (n = 3.0). Typical error of a single measurement is about 1 mm.

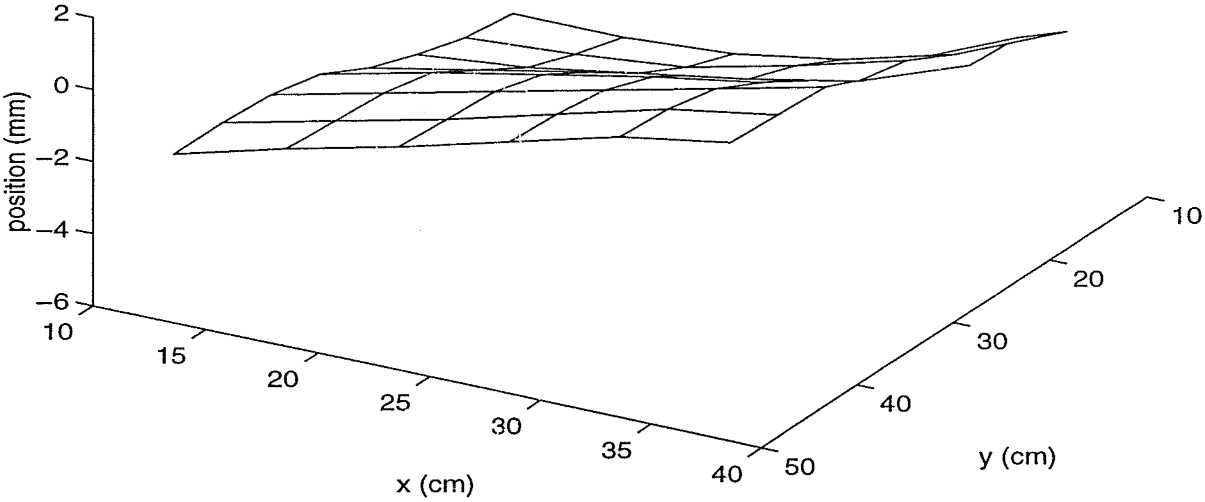


Figure 2. Measured levels of the upper surface of the brick.

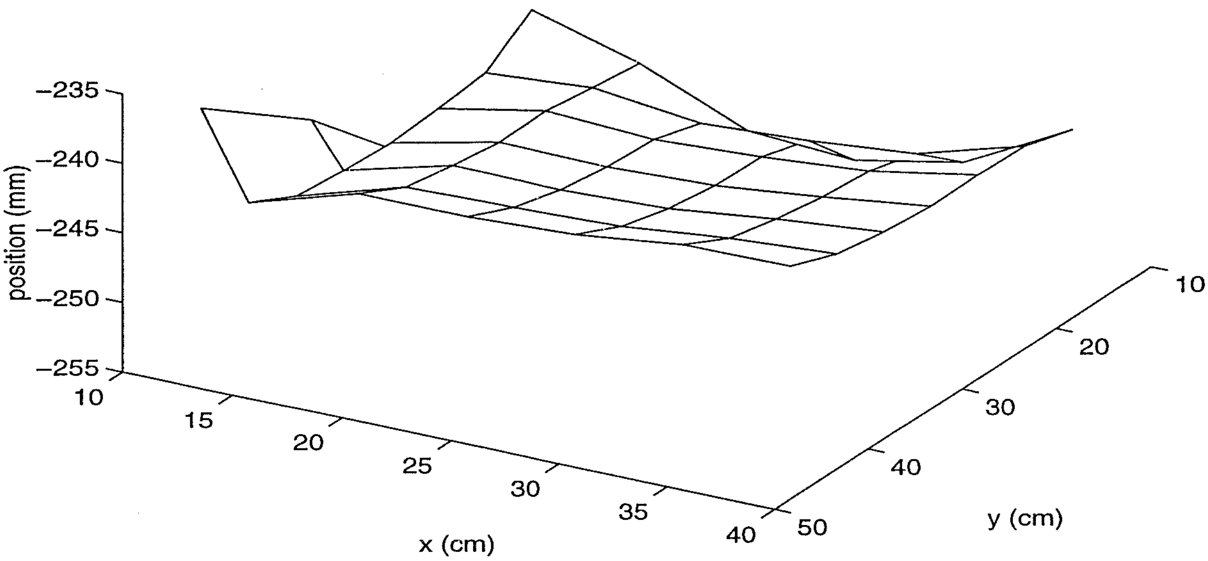


Figure 3. Measured levels of the lower surface of the brick.

Figures 4 shows the true position in space of the two surfaces. Both surfaces are relatively flat at this scale, with a slight bend towards the outer rims. Figure 5 shows the measured thickness of the ceramic brick. The brick is thickest in the center at about 81 mm and is slightly thinner at the outside rim of the y-axis at about 79 mm. This curvature has been verified by measurements with a ruler over the two surfaces.

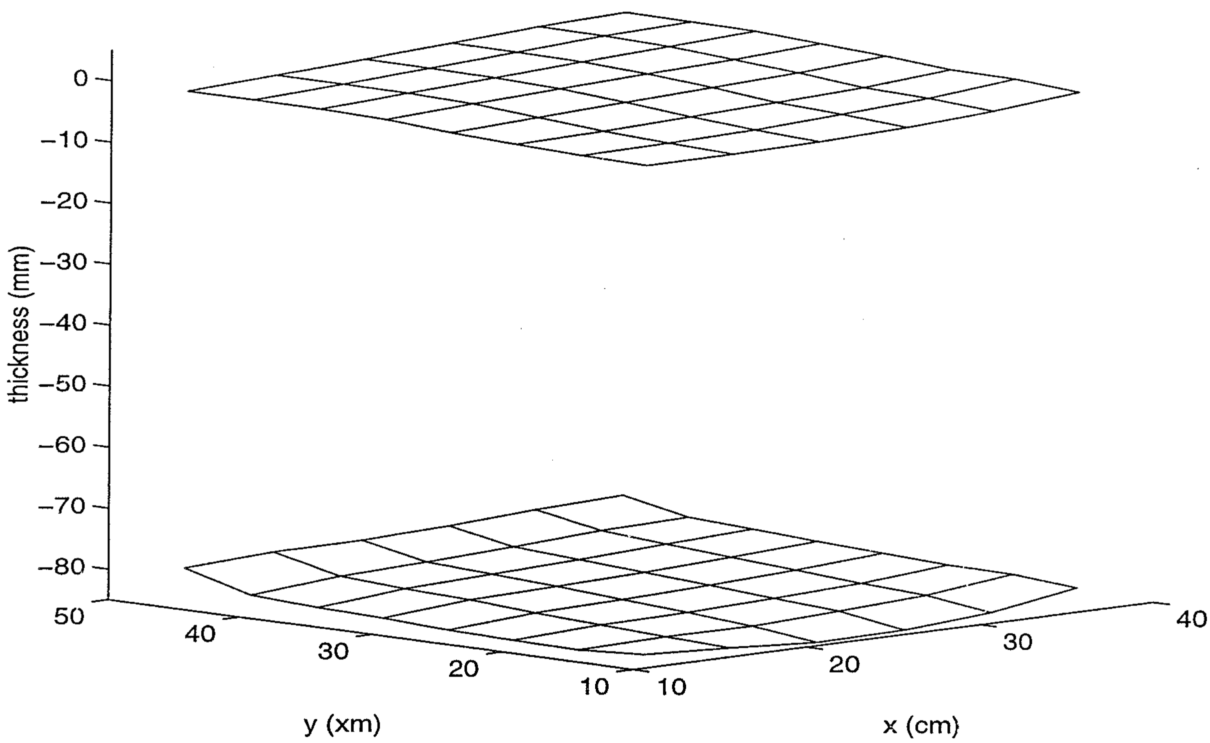


Figure 4. The upper and true lower surfaces of the brick.

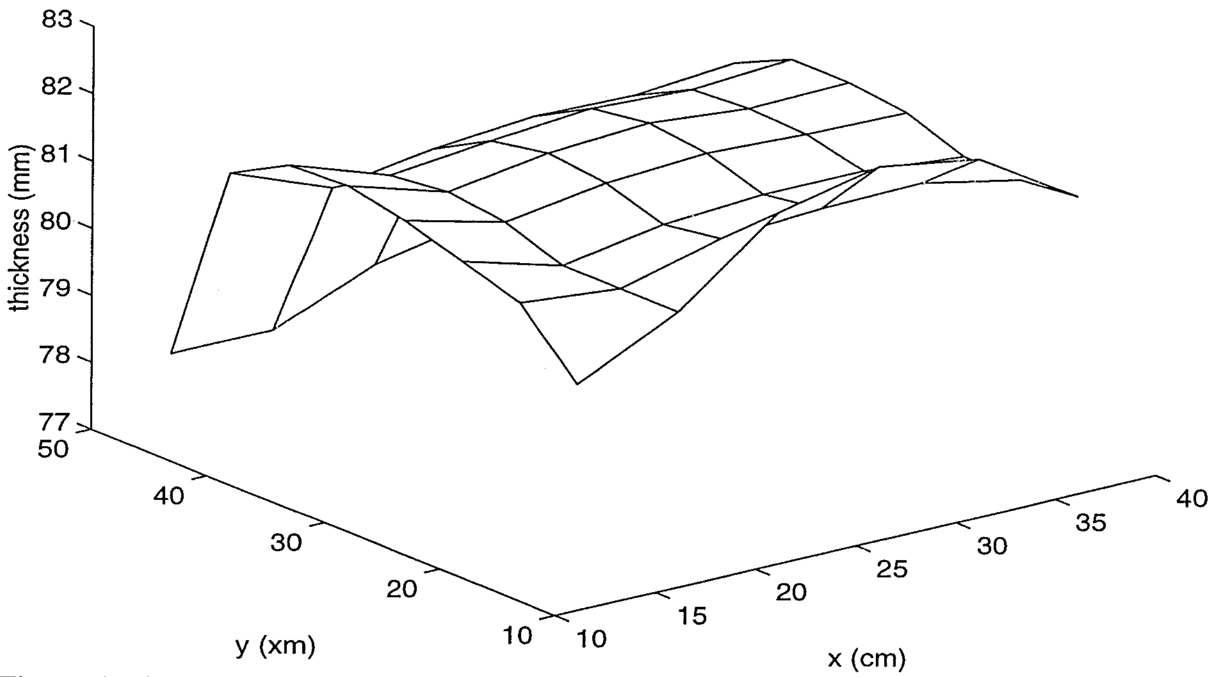


Figure 5. The true thickness of the brick measured in mm over the surface.

## CONCLUSION

We conclude that radio wave interferometry can be used to measure the thickness of the refractory material. The frequency range used for these measurements was 10-15 Ghz which seems to be optimal with low attentuation (about 0.15 dB/cm of refractory material) and high resolution (about 1 mm).

We suggest a further collaboration between Pilkington Halmstad and CIST at the University of Halmstad with the aim to develop a technique to measure the thickness of the refractory material from the outside and on-line without any disruption to the industrial process.

The final aim should be a workable prototype to be mounted for longterm tests on the glass furnace at Pilkington Halmstad.

Halmstad 23 January 1996

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