Blast Furnace Burden Topography

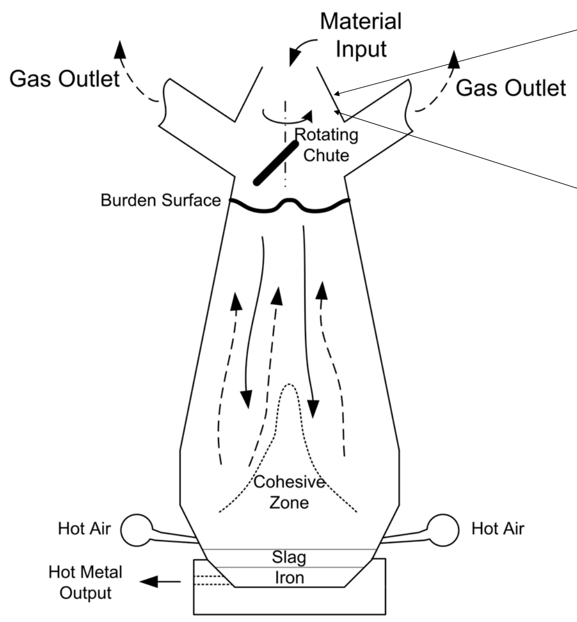
E.J.Nilsson[1], L.B.Baath[1] and D.Malmberg[2]

[1] *Halmstad University, Sweden*

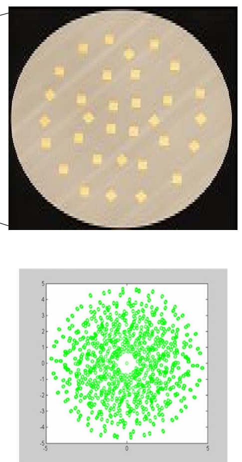
[2] *MEFOS, Metallurgic Research Institute, Sweden*

INTRODUCTION

Within the global steel- and metal industry there is a growing need for new sensor systems to measure and control the industrial process. New technologies for new sensors are continuously being developed for an ever growing market. The growth in the steel making industry is based on ore and Blast Furnaces therefore play an increasingly important role for the production of hot liquid iron and steel. We present a new interferometer micro wave system to make three dimensional topographic maps of the blast furnace burden surface. The Blast Furnace process is one of the oldest industrial processes. The furnace is tall and round. Layers of Coke ands iron ore are successively laid, and air, pre-heated to 1200 °C, as fuel to the process. The coke and iron layers become semi-liquid and then liquid in the cohesive zone. The carbon from the coke reacts with the oxygen in the ore (which is Fe_2O_3 or Fe_3O_4) and form CO and CO_2 which goes off as off-gas. The iron, now mixed with some amount of carbon, is tapped in liquid form from the bottom. This is then taken to a converter, where oxygen is added to remove the carbon to form the final product of liquid steel.



Sketch of a Blast Furnace. Material is added on top via a chute as layers of coke and ore.



The interferometer array designed by us for the Blast Furnace application (upper panel) is mounted inside the Blast Furnace. The corresponding aperture plane coverage is shown in the lower panel.

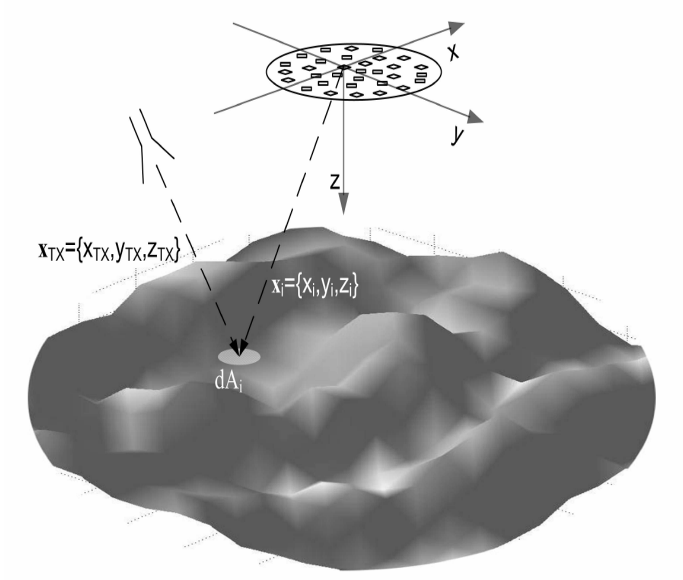


Figure showing the concept of our interferometer system. The optical axis of the interferometer is along the Z-axis.

TECHNOLOGY

It is important for the process that it remains symmetric. Therefore it is increasingly necessary to measure the burden topology and profile. Today single profile meters are used which include substantial mechanical and hydraulic arrangements. The topography is then modelled by assuming symmetry. Our novel approach has no moving parts and can be placed stationary at a single vantage point near the blast furnace top. By sending a series of microwave mono-chromatic waves from a single point and receive their reflection off the surface burden at a number of other points, it is possible to extract a three dimensional image of the blast furnace whole burden topography. The receiver is based on technology used in radio astronomy, applied to an industrial environment. The technology is described in our IEEE paper [1]. This technique makes it possible to see through dust and gas which obstruct ordinary optic monitoring and gives a sufficient high resolution. Our interferometer system is situated at the top of the plant, at the same level as the charging chute. The interferometer can be placed at an angle, as long as the view of the burden is unobstructed. The basic principles are as follows:

- A number of narrow frequency channels are successively transmitted towards the surface.
- The reflected channels are received at each interferometer element.
- The signal for each element is Fourier transformed from frequency space to delay space. The delay channels form concentric spheres of received signals.
- Every pair of elements are then combined for each delay channel (delay sphere).
- The set of pairs form the aperture plane and this is then Fourier transformed into an angular plane.

This procedure results in a spherical co-ordinate system, where the radius is the delay and the angular position is returned from the aperture plane transform. The only assumption made is that the surface is in the far-field of the interferometer, i.e. the phase centre of the reference for each element pair coincides with the optical axis of the interferometer system.

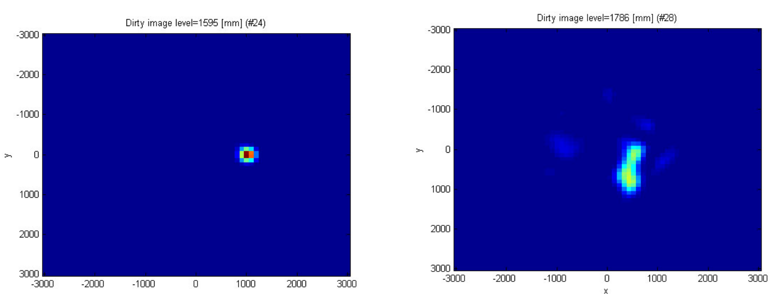


Image of reflection from a metal target at distance from the interferometer array. Left panel shows a simulation with perfect data. Right panel shows a real measurement.

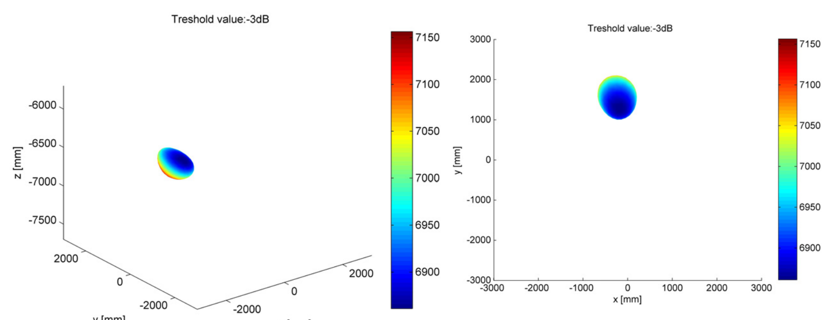


Image of test coke surface as the difference between the original surface and the surface after a small dip has been made. Left panel shows the 3dB image in three dimension. Right panel shows the same, but seen from the top, along the line of wave propagation.

EXPERIMENTAL TESTS

We have performed a series of experimental tests of the technology. These have been more substantially described in a Licentiate thesis [2]. The point-spread function (beam) of the system was determined by first simulating a point source at 1.5 m distance and then observing a differential image with a hole made in a coke surface at a distance of 1.7 m. The simulation indicates a clear round beam, while the observed beam showed some side-lobe structures. Some of these erroneous structures are caused by that the experiment target is not a perfect point source. Some of the side-lobe structures are caused by that our primary assumption is not quite correct. The positions of the reference point are translated for each element pair, resulting in a slight ellipsoid aberration of the interferometer optics. The data also need to be calibrated for cross-talk between antennae and Speckle formed at the burden surface. Work is presently going on to make a new data reduction algorithm, where the data are treated in true three dimensional format. A model of the surface is constructed from known a priori data, and then fitted to the observed complex data with a maximum entropy method.

The three dimensional beam is shown in the figure above. We have demonstrated that an object can be detected and measured in three dimensions [2] with sufficient accuracy for a Blast Furnace surface.

REFERENCES

[1] E.Nilsson and L.Baath, “Radar Interferometric Measurements with a Planar Antenna Array”, Journal of IEEE Sensors (2007)

[2] E.Nilsson,, “Sensor Platform for 3D Microwave Interferometry Imaging,”, Licentiate Thesis, Chalmers University of Technology (2006)