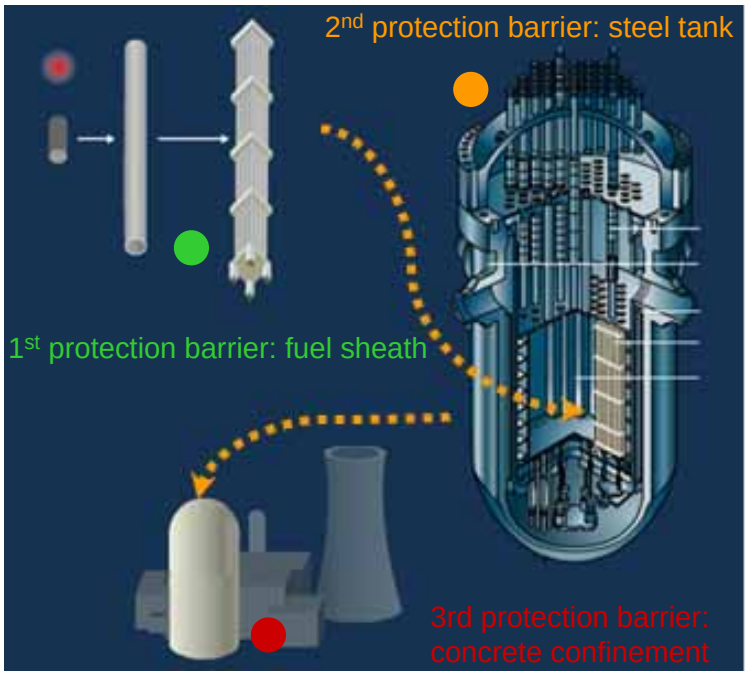
Concrete NDT using low-frequency phased arrays (1/3)

This article is based on two CEA publications: Study of phased array techniques for concrete inspection, O. Paris, C. Poidevin, J.M. Rambach, and G. Nahas, to be published in Proc. Review of Progress in Quantitative NDE, 2007, and Caractérisation non destructive, ultrasonore de défauts susceptibles de dégrader les bétons d'enceinte, O. Paris, G. Ribay, and J.M. Rambach, presented at COFREND 2007 (Annual Meeting of the French Society for NDT).

The third and final protection barrier confining nuclear reactors is usually a concrete containment structure (see figure below). Monitoring the structural integrity of these barriers is critical in ensuring the safety of nuclear power plants. The responsibility for plant safety in France lies with the IRSN, who collaborated with the CEA and M2M to develop an ultrasonic phased-array technique capable of inspecting 1.2m-thick concrete walls. The NDT method must be able to detect cracks and bulk defects.



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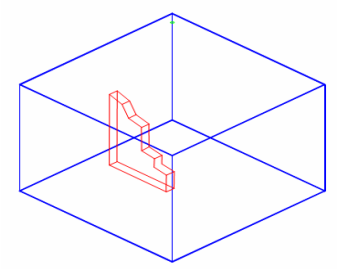
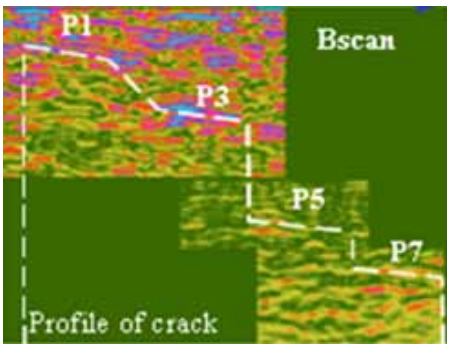
Concrete NDT using low-frequency phased arrays (2/3)

Given the thickness of the structure undergoing inspection and the heterogeneity of the concrete, the optimal frequency lies in the 50-300kHz range. At these frequencies, the ultrasonic beam profiles are widespread (non-directive) with poor signal-to-noise ratios (SNR). Using phased-array techniques (e.g., beam focusing and beam steering), the objective is to improve detection resolution and sizing accuracy, as well as to validate NDE simulation tools for heterogeneous material.

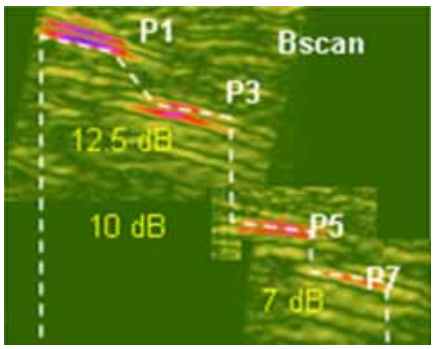
Experiments are carried out on a representative concrete block containing artificial defects (see figure below) using the MultiXLF (low-frequency phased-array system from M2M) and the modeling is performed using the CIVA simulation platform.



Two sets of measurements are carried out. One data set is obtained by performing a raster scan with a conventional transducer, while the other set of measurements applies phased-array techniques using an 8-element transducer at 250 kHz in conjunction with image reconstruction inspired by SAFT processing (synthetic aperture focusing technique). The substantial improvement in resolution is evident in the following figure.



Conventional probe measurements



Post-processed low-frequency phased-array measurements

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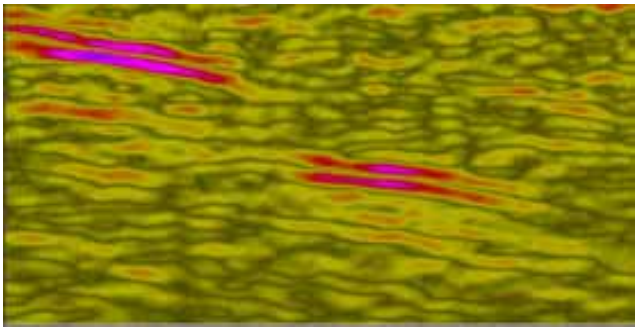
Concrete NDT using low-frequency phased arrays (3/3)

In order to fulfill the simulation objectives of this study, attenuation and noise models have been implemented in CIVA.

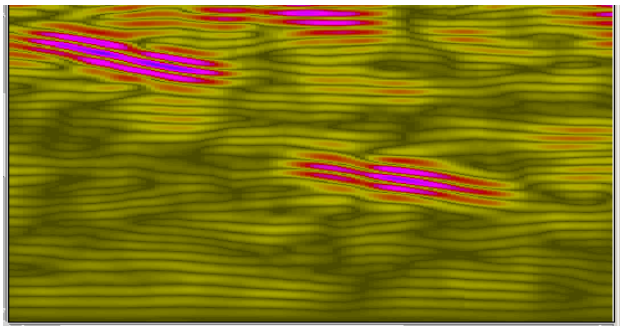
The Waterman & Truell homogeneous model is used to account for attenuation in the concrete. Taking as input the acoustic properties of the mortar matrix material and a distribution of spherical scatterers, this approach represents the concrete as an equivalent homogeneous medium for the calculation of attenuation versus frequency.

To predict the noise contribution, the specimen description is augmented to include a set of randomly distributed scatterers with specific reflectivity properties. Their echoes in the time domain are used to represent the noise contribution.

The results of a validation exercise are displayed in the following figure, in which the measurements made on the concrete specimen using the M2M low-frequency phased-array technique are compared to the simulated results obtained from the CIVA software. Excellent agreement is obtained.



MultiX LF B-Scan measurements



CIVA B-Scan simulation

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