REDUCTION OF THE MODEL NOISE IN NON-LINEAR RECONSTRUCTION VIA AN EFFICIENT CALCULATION OF THE INCIDENT FIELD : APPLICATION TO A 434 MHz SCANNER

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Introduction

For a decade, microwave tomography has been drastically boosted by the developpement of efficient reconstruction algorithms based on an iterative solution of the corresponding non-linear inverse problem. Distorted Born Method [1] and Newton Kantorovich Techniques [2] are two equivalent approaches where the measured scattered field is iteratively compared to the scattered field calculated from a numerical model, the dielectric contrast of which is adjusted for minimizing the error on the scattered fields. In such approaches, the so-called model noise refers to the disability of the numerical model to reproduce the experimental setup. The model noise has an evident and direct impact on the quality of the reconstructed images [3,4]. More particularly, the accuracy of the electric field radiated by the antennas of a microwave scanner, inside the target area, has been shown to play a significant role on the overall image quality. Taking into account the antenna environment, like the boundary wall supporting the antenna array of the scanner, is of prime importance, especially when operating at low frequency. For instance, the wall of a 60 cm diameter whole-body microwave scanner cannot be neglected at 434 MHz, even when using the immersion technique consisting to put the target in water. Indeed, at such a frequency, the attenuation introduced by water is not sufficient to avoid multiple reflections on the scanner boundary walls. Consequently, the way of calculating the incident field constitutes a key factor in iteratively solving non-linear inverse problems. The selected technique must accommodate high accuracy while maintaining acceptable calculation complexity. In this paper, three distinct techniques are analysed. They are based on the use of i) free-space and ii) non free-space Green's function, and iii) on a FDTD approach. All these techniques have been firstly investigated under their 2D version, for being used in 2D reconstruction algorithms. However, the scattered field data are collected in a 3D scanner. For assessing the validity of the previous 2D techniques, their results have been compared to both experimentally and 3D-FDTD results.

Scanner configuration

In this paper, a whole-body microwave scanner configuration is considered. A fully electronically scanned version is under development for obtaining rapid acquisition. This new advanced prototype is expected to improve the results previously obtained with an early version using mechanical scans of both transmitting and receiving biconical antennas [5]. The microwave scanner array is circular and consists of 64 multiplexed printed circuit H-type E-polarized antennas, operating either in a transmitting or receiving mode (figure 1). For modelling purposes, each antenna is assumed to radiate in water in presence of a 59 cm diameter conducting circular cylinder. This cylinder is infinite in the 2D case or finite, 35 cm high, in the 3D case . At the 434 MHz operating frequency, water exhibits a relative dielectric constant $\varepsilon = 78 + j4$, the wavelength in water is equal to 7.7 cm and the attenuation constant is about 0.2 dB/cm.

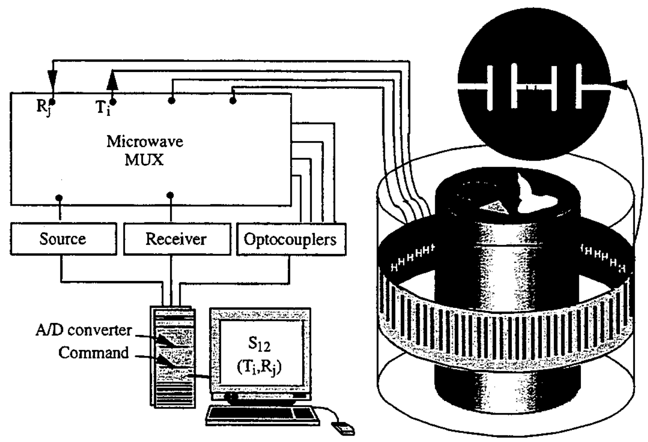


Figure 1: Schematic view of the 434 MHz scanner under developpement

Results

Figure 2 shows the amplitude/phase field distribution measured by a biconical probe in the central plane of the scanner. The metallic wall produces visible reflections, especially far from the transmitting antenna.

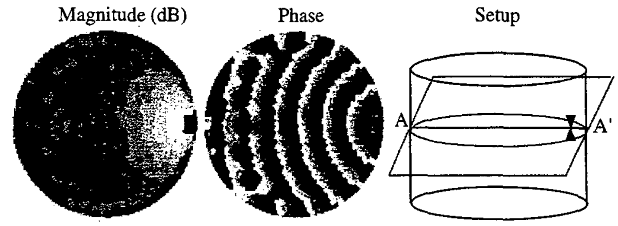
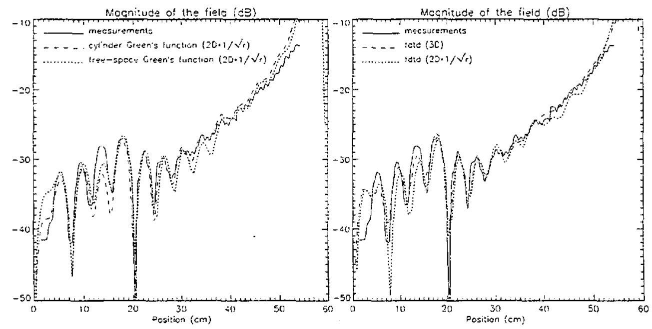


Figure 2: Measurements of the field radiated by a biconical antenna

The simplest way for calculating the incident field radiated in such a scanner geometry is to consider the transmitting antenna as an infinite electric line source located inside a conducting cylinder of infinite length. The calculation of the incident field can then be performed, either i) by using the free-space Green's function and taking into account the metallic cylindrical wall as a scatterer, or more directly ii) by using the Green's function of the circular cylinder. In the first case, the incident field is obtained after solving a scattering problem by means of the method of moment [6], while, in the second one, it is derived from an explicit series of Bessel functions [7].



Figures 3a-3b: measured and computed incident fields on line AA' (cf. figure 2)

The results obtained by means of these two techniques are given in figure 3a and compared to the previous measurements. In order to improve the dependence with distance and fit the averaged expected 1/r decrease of 3D field distribution with distance, the 2D numerical results have been multiplied by a $1/\sqrt{r}$ factor. Figure 3a shows a good agreement between the two numerical techniques and the experimental results. In the region where the incident and the reflected waves interfere, the error between experimental and calculated fields is of the order of 2 dB. As shown on figure 3b, it also appears that the 2D-

FDTD code provides a good agreement with experimental results, except in the very close vicinity of the metallic wall, where the measurement accuracy is questionable, due to possible probe-wall interactions. Interesting is also the fact that the 2D- and 3D-FDTD codes provide very comparable results (error about 1 dB), even if the 3D results fit a little bit better the experimental results. Of course, this results from the fact that in the 3D code, the antenna is modelled by a dipole of finite length ($\lambda/2$), and not by a line source of infinite extent. The 3D simulations have been conducted on a SGI O2000 parallel computer of CEPBA. The largest simulation used a mesh of 85x85x200 cells with a resolution of 0.1 wavelength in water. The required 7,600 iterations were performed in 1h38' with 8 parallel processors. The 3D-FDTD code has made possible the calculation of the cross-polar electric field component which is very low in the median plane of the scanner.

Conclusions

Those results have allowed to classify the different techniques according to their i) accuracy, ii) computation cost (time/memory), iii) easiness of integration in non-linear reconstruction algorithms and iv) flexibility in realistically taking into account the most relevant details of the scanner prototype. A thorough investigation of the influence of the model noise, resulting from incident field inaccuracy, on the global image will be presented.

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