

of aluminum (Al) at 24 keV and with a volumetric mass density corresponding to 60% of the Al density, i.e. 1.63 kgm^3 , were designed. The choice of 24 keV corresponded to the photon energy of the x-ray source used in our study. Al is less attenuating than the minerals composing real μcalc which contain calcium carbonate, calcium oxalate or apatite. This is realistic since in real (μcalc), the minerals are embedded in a protein matrix; therefore the attenuation of a (μcalc) is lower than when considering only the minerals.

5.2.2 Physical characteristics

Physical characteristics of the imaging system were modeled as follows. A simplified mono-energetic x-ray source was used. The photon energy level was set to 24 keV, this is equivalent to the effective x-ray energy of a 34 kVp Rhodium (Rh)/Silver (Ag) target/filter spectrum used for imaging a 46 mm compressed breast. An ideal point source focal-spot was used. In order to simulate the detector unsharpness, a modulation transfer function empirically measured from the reference system was used by the simulator. X-ray scatter from the test object was not considered. Only Poisson x-ray noise was added and the electronic noise was not modeled.

A calibration was performed to match the signal-to-noise ratio (SNR) in simulated images with the SNR obtained in experimentally acquired images using the GE Senographe Pristina system with automatic optimization of parameters. The adjustment method is described as follows. On the GE Senographe Pristina system, FFDM central raw projection images were acquired from 2 phantoms (CIRS, Virginia, USA) with 100% adipose and 100% fibroglandular equivalent composition. The phantoms were positioned side-by-side on the breast positioning table. The acquisitions were repeated for five different breast thicknesses $\{45, 50, 60, 65, 70 \text{ (mm)}\}$. Images of the 45mm thick phantom was acquired at 26 kVp, the images of the others four phantoms were acquired at 34 kVp. A Rh/Ag target/filter combination was used with the AOP mode. SNR values were measured in the raw projection images (processed only with the manufacturers gain, offset, and defective pixel correction), in $2\text{cm} \times 2\text{cm}$ square ROIs at 5 cm from the chest wall. SNR was defined as $\frac{\langle SI \rangle}{\sigma_{SI}}$, where $\langle SI \rangle$ is the average detected signal intensity per pixel and σ_{SI} is the standard deviation in the signal intensity. The corresponding experiments was then simulated. The mAs value in the simulation was adjusted so as SNR values in the simulated and experimentally obtained images were found similar. Due to restrictions of the x-ray simulator, it was not possible to exactly match the SNR for both 100% adipose and 100% fibroglandular regions. The mAs in the simulations was therefore adjusted till SNR differed by maximum 10% in both breast-tissue equivalent.

5.3 Compression quality metrics

The measures used to quantify the three criteria characterizing the quality of breast compression (patient comfort, image quality and average glandular dose) are described in the following section.