Fusion of Digital Breast Tomosynthesis and Microwave Radar Imaging for a High Contrast Breast Cancer Imaging Algorithm

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The proposed contribution is a breast cancer detection and imaging algorithm which fuses information gathered from Digital Breast Tomosynthesis (DBT) and microwave Nearfield Radar Imaging (NRI) to improve the contrast between cancerous lesions and healthy high water content (HWC) tissue. DBT is a computed tomography technique described in [1] which generates 3D images that are significantly better than the 2D images generated through conventional mammography. However, DBT remains subject to the relatively low contrast (~1\%) in X-Ray attenuation between healthy HWC tissue (such as fibrous-connective or glandular tissue) and cancerous lesions. In microwave bands, the physical contrast in dielectric properties is much higher (~10\%) [7] but the resultant anomalous component of the scattered field is very small compared to the measured total field and is very difficult to detect.

The proposed hybrid DBT–NRI algorithm, also described in [2–6], uses the DBT image to establish the 3D geometry of the internal inhomogeneous tissue. If the X-Ray attenuation is assumed to be a function of the tissue density, the issue is addressed by estimating some of the tissue density distribution. The inhomogeneous distribution of adipose content in healthy breast tissue and the dielectric constant and conductivity at the frequency of interest.

Once the assumed healthy distribution of complex permittivity is known, a computational modeling tool such as 3D Finite Difference Frequency Domain (FDFD) can be used to simulate the propagation and scattering of electromagnetic waves in the inhomogeneous medium [8]. This simulated assumed healthy case $E^{HC}$ is then subtracted from the measured case $E^{C}$ in order to highlight any anomalous difference generated by the deviation, at the lesion position, from the expected healthy case. The anomalous component of $E^{C}$ generated in this way is therefore defined as $E^{A} = E^{C} - E^{HC}$.

While $E^{HC}$ is defined at every point in the 3D volume of interest, physical measurements can only be performed outside the tissue and as a result, $E^{C}$ and $E^{C}$ are only available at the positions of receiving antennas. The breast tissue is assumed to be secured in compression paddles during co-registered DBT and NRI measurements with $N$ ideal transmitting antennas are distributed on one compression paddle and $P$ ideal receiving antennas are distributed on the opposite paddle. Once the anomalous scattered field $E^{A}$ has been computed for several different frequencies, the lesion position can be imaged using the following Synthetic Aperture Radar (SAR) formula:

$$I(r_u) = \sum_{n,l,p} E^{A}(f^{l},r^{n}_{r},r^{p}_{r}) e^{i[\Phi^{p}_{n}(f^{l},r^{n}_{r},r_{u}) + \Phi^{p}_{n}(f^{l},r^{n}_{r},r_{u})]}$$

where $I(r_u)$ represents the reconstructed image at the point $r_u$, $E^{A}(f^{l},r^{n}_{r},r^{p}_{r})$ represents the anomalous component of the scattered electric field (with $e^{-j\omega t}$ time dependence) generated on the $p^{th}$ receiving antenna located at $r^{p}_{r}$ when the $n^{th}$ transmitting antenna, located at $r^{n}_{r}$, is radiating with the $l^{th}$ frequency $f^{l}$. The phase terms $\Phi^{p}_{n}(f^{l},r^{n}_{r},r_{u})$ and $\Phi^{p}_{n}(f^{l},r^{n}_{r},r_{u})$ represent the phase produced by the $n^{th}$ transmitting antenna, or $p^{th}$ receiving antenna respectively, on the imaging point $r_u$ and can be estimated using 3D FDFD. The image $I(r_u)$ generated in this way shows a clear anomaly centered at the actual lesion position in all three dimensions. This technology has the potential to reduce false negatives as well as false positives in a clinical breast cancer screening setting.
References


