Microwave imaging of dielectric targets by means of an inexact-Newton method in L^p Banach spaces and multifrequency processing

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The reconstruction of the distributions of the dielectric properties of unknown targets by using interrogating microwaves is a topic that has been widely investigated by the scientific community in the last years (M. Pastorino, *Microwave imaging*, John Wiley, 2010). In this framework, the present authors have developed an approach based on an inexact Newton method (C. Estatico et al., *IEEE Trans. Antennas Propag.*, **60**, 2012, pp. 3373–3381), which has been found to be quite efficient in finding a regularized solution of the associated electromagnetic inverse scattering problem with a spatial resolution beyond the Rayleigh limit (since it is developed in the spatial domain).

In this contribution, the mentioned approach is extended to deal with multifrequency data acquired in a multi-illumination multiview set up. In this way, it is possible to fully exploit the increased information content of the scattered fields. The considered method is a two-step procedure composed by two nested iterative loops, in which the nonlinear scattering operator is firstly linearized by means of a Gauss-Newton approach (outer loop), and the resulting linear system is solved in a regularized way with truncated Landweber iterations (inner loop). This regularization step is performed in the framework of Banach spaces for reducing the over-smoothing and ringing effects usually introduced by Hilbert space approaches. In particular, the method minimizes the Banach space L^p norm of the residual $\Phi(\mathbf{x}) = 1/2\,\|\mathbf{F}(\mathbf{x}) - \mathbf{y}\|_{L^p}^2$, where $\mathbf{F}$ is the nonlinear scattering operator which maps the unknown function $\mathbf{x}(\mathbf{r}) = [\epsilon_r(\mathbf{r}) - 1 \quad \sigma(\mathbf{r})]^T$ on the scattered electric field measurements collected at F different frequencies (which are contained in the array $\mathbf{y}$).

An example of the results obtained considering the reconstruction of cylindrical dielectric targets under transverse magnetic illumination conditions is shown in the following. Two separate lossless circular cylinders of radius 0.125λ and 0.25λ (being λ the free space wavelength at the central frequency) and dielectric permittivities equal to $3\epsilon_0$ and $2\epsilon_0$, respectively, are considered. Simulated scattered field data at $F = 3$ frequencies (200, 300, 400 MHz) are used. In details, they have been generated by using the moment method for solving the forward scattering problem and corrupted with a Gaussian noise with signal-to-noise ratio $SNR = 20$ dB. The relative mean squared error ($NMSE$) versus the L^p norm parameter p is shown in Fig. 1(a). As can be seen, working in Banach spaces (with $p < 2$) allows to obtain lower errors, especially when a reduced number of frequencies is considered. For completeness, two examples of the reconstructed permittivity are reported in Fig. 1(b) and Fig. 1(c), which confirm that the multifrequency processing in Banach spaces is capable of providing significant improvements in the overall reconstruction quality.

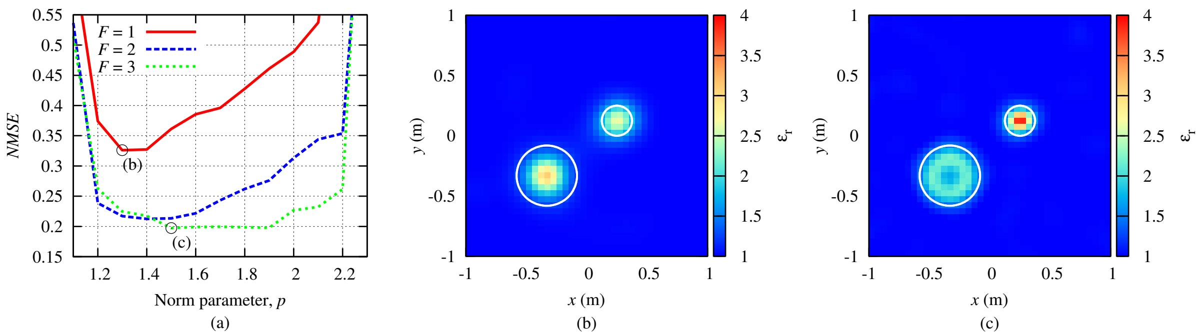

Fig. 1. (a) Normalized mean squared errors versus the value of p for different numbers of considered frequencies F. Reconstructed distributions of the relative dielectric permittivity: (b) one frequency, $p = 1.3$; (c) three frequencies, $p = 1.5$.