Design of Biomedical Array Applicators: an Innovative Constrained Synthesis Strategy to focusing Vector Fields

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Spatially focusing a wave field into a target point is an open topic of remarkable interest for the scientific community both from the theoretical and applicative point of view. Designing applicator able to focus a field into a target point is required in many biomedical applications such as hyperthermia, imaging, activation of chemical or biological processes or remotely heat-controlled drugs release. In those cases, the main objective of suitable synthesis procedures is designing a source (typically the excitations of an antenna array) able to induce a selective power deposition in a target point while keeping its value below prescribed levels elsewhere in order to avoid unwanted side power peaks.

Some interesting solutions applicable to scalar fields are already available in literature such as the well known Time Reversal (TR) approach (M. Fink, *IEEE Trans. Ultrason. Ferroelec. Freq. Contr.*, **39**, 1992, pp. 555–566) or the Optimal Constrained Power Focusing (OCPF) technique for scalar fields (D. A. M. Iero *et. al*, *Prog. in Electromag. Res.*, *PIER*, **102**, 2010, pp. 125-141). The latter recasts the synthesis problem into a convex programming (CP) one guaranteeing the achievement of the globally optimal solution in an effective and efficient way without recurring to global optimization techniques, which are extremely heavy from the computational point of view. The approach is very general, and outperforms the former one, thanks to its ability in control the side power deposition (D. A. M. Iero *et al.*, *IEEE Antennas Wireless Propag. Lett.*, **12**, 2013, pp.1029-1032).

On the other side, both techniques cannot be applied to generic vector (i.e. electromagnetic) fields directly as several issues arise due the intrinsic vector nature of the field. In fact, when moving to the case of vector fields, the underlying optimization problem is a non-deterministic polynomial-time hard (NP-hard) one. Hence, some alternative strategy has to be devised to preserve the capability of achieving the global optimum, while controlling side power deposition. To this end, we propose and discuss an innovative deterministic and globally effective approach, which consists in the introduction of an auxiliary multi-objective problem, whose Pareto front can be determined by solving a number of different single-objective CP problems. As known, these latter can be efficiently solved via local optimization techniques. Then, the globally optimal solution of the original problem is simply determined as the maximum energy point of the achieved Pareto front. To the best of our knowledge, this is the first time that such a strategy has been applied to tackle the NP-hard problem of focusing the electromagnetic power carried by a vector field in presence of constraints.

A comprehensive presentation of the overall constrained focusing strategy will be given at the conference, supported by interesting numerical examples and performance comparisons with TR.