

PATIENT-SPECIFIC FOCUS STEERING IN ANULAR AND BOWL-SHAPED PHASED ARRAYS USED IN MR-MONITORED HYPERTHERMIA TREATMENT

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ABSTRACT

Purpose: The ability to control the position and profile of the heating pattern determines the efficacy of hyperthermia treatments. In the case of deep seeded tumors, such as breast tumors and extremities' sarcomas, patient's discomfort associated with the overheating of sensitive regions of normal tissue, often limits the treatment dose. This effect can be significantly reduced with an accurate control of the temperature distribution within the target region. In radiofrequency phased arrays, phase and amplitude determine the outline and the location of the power deposition and consequently of the heating. Recent advances in MR imaging allow for non-invasive real-time 3D monitoring of temperature differences inside the body. In certain cases, when MR imaging is not available, a set of 2 or 3 invasive temperature probes can give sufficient information about the thermal map of the treated volume. The control software developed at Duke University allows the clinician to choose between manual, semiautomatic or fully automatic control based on temperature information received by MR images or multiple fluoroptic probes. Using the semiautomatic method presented here, the clinician can reshape and relocate the heating pattern within a large set of positions and shapes obtained interpolating pre-calculated power distributions in relatively complex geometrical models derived from the actual anatomical features of the patient.

Methods: The semi-automatic method uses relatively complex geometrical model derived from anatomical images (MR or CT). The model is used to calculate a priori a set of position and shapes that can be obtained with several amplitude and phase combinations. Initially an MR or CT image is imported in Ansoft HFSS and IMST Empire. The two programs use frequency and time domain simulation respectively to determine the electromagnetic field distribution inside the concave array structure (anular to treat extremities or bowl-shaped for breast). Amplitude and phase can be set in post-processing to determine the power deposition patterns corresponding to each setting. A set of 5 normalized amplitudes (0, 0.25, 0.5, 0.75, 1) and 10 phase settings (-180 to +144, every 36 degrees) per antenna has shown to be sufficient to accurately to describe most of the feasible patterns. The position of the maximum power (X_{Max} and Y_{Max}) and the half power beam size (L_x and L_y) for the settings not obtained by the simulation are obtained by interpolation using Matlab. Using Labview as the control software, the beam can be steered and formed in any interpolated position and shape.

Results: The semiautomatic method has been tested in homogeneous and inhomogeneous phantoms. The power deposition pattern is measured with an isotropic SAR probe in a tissue equivalent liquid. The experiments confirm the simulation results:

- The center of the focus can be simply moved in the target volume mostly modifying the phases
- The closer the beam is to an antenna, the lower the power of that antenna is set to maintain the beam shape
- The system symmetry cannot be exploited in non-homogeneous phantoms where the preservation of the shape of the half power beam deforms at the interfaces between tissues
- The thickness of the water bolus affects both power and phase settings

Conclusion: A method that allows the clinician to accurately control in a semiautomatic and intuitive way the beam position and shape has been developed. Based on anatomical images of the patient, a series of phase and amplitude sets associated with several positions and shapes of the focal region is determined using commercial simulation software. Additional sets are obtained by interpolation. The method has been verified experimentally with success.