ALIDX-500

Area:
During an area scan, global and local maxima searches are automatically performed in
2-D after each Area Scan measurement with at least 6 measurement points. It is based on the
evaluation of the local SAR gradient calculated by the Quadratic Shepard's method.

Zoom:
For dosimetric application, it is necessary to assess the peak spatial SAR value averaged over a
volume. For this purpose, fine resolution zoom scans need to be performed at the peak SAR
location(s) determined during the Area Scan. These scans are called Zoom Scans. The default
Zoom Scan measures 7 x 7 x 7 points with a step size of 5mm. Faster evaluations can be
achieved with a reduced number of measurement points. For example, a Zoom Scan with a grid
step size in x- and y-directions of 7.5 mm (5 x 5 x 7 cube configuration) reduces the
measurement time to almost half with only 1-2% difference in SAR reading compared to the fine-
resolution 7 x 7 x 7 scan.

Extrapolation Procedures:

Extrapolation routines are used to obtain SAR values between the lowest measurement points
and the inner phantom surface. The extrapolation distance is determined by the surface detection
distance and the probe sensor offset. Several measurements at different distances are necessary
for the extrapolation.

Extrapolation routines require at least 10 measurement points in 3-D space. They are used in the
Zoom Scan to obtain SAR values between the lowest measurement points and the inner phantom
surface. The routine uses the modified Quadratic Shepard's method for extrapolation. For a grid
using 7x7x7 measurement points with 5mm resolution amounting to 343 measurement points, the
uncertainty of the extrapolation routines is less than 1% for 1 g and 10 g cubes.

Boundary Effects:

For measurements in the immediate vicinity of a phantom surface, the field coupling effects
between the probe and the boundary influence the probe characteristics. Boundary effect errors
of different dosimetric probe types have been analyzed by measurements and using a numerical
probe model. As expected, both methods showed an enhanced sensitivity in the immediate
vicinity of the boundary. The effect strongly depends on the probe dimensions and disappears
with increasing distance from the boundary. The sensitivity can be approximately given as:

$$S \approx S_o + S_b exp(-\frac{z}{a})cos(\pi\frac{z}{\lambda})$$

Since the decay of the boundary effect dominates for small probes (a <<λ), the cos-term can
be omitted. Factors S_b and a are assessed during probe calibration and used for numerical
compensation of the boundary effect. Several simulations and measurements have confirmed
that the compensation is valid for different field and boundary configurations.

This simple compensation procedure can largely reduce the probe uncertainty near boundaries. It
works well as long as:

• the boundary curvature is small
• the probe axis is angled less than 30° to the boundary normal
• the distance between probe and boundary is larger than 25% of the probe diameter
• the probe is symmetric (all sensors have the same offset from the probe tip)

Since all of these requirements are fulfilled in the ALIDX-500 system, the correction of the probe boundary effect in the vicinity of the phantom surface is performed in a fully automated manner via the measurement data extraction during postprocessing.

Spatial Peak and 1g averaging:

The interpolated data is used to average the SAR over the 1g and 10g cubes by spatially discretizing the entire measured volume. The resolution of this spatial grid used to calculate the averaged SAR is 1mm or about 42875 interpolated points. The resulting volumes are defined as cubical volumes containing the appropriate tissue parameters that are centered at the location. The location is defined as the center of the incremental volume (voxel).

The spatial-peak SAR must be evaluated in cubical volumes containing a mass that is within 5% of the required mass. The cubical volume centered at each location, as defined above, should be expanded in all directions until the desired value for the mass is reached, with no surface boundaries of the averaging volume extending beyond the outermost surface of the considered region. In addition, the cubical volume should not consist of more than 10% of air. If these conditions are not satisfied then the center of the averaging volume is moved to the next location. Otherwise, the exact size of the final sampling cube is found using an inverse polynomial approximation algorithm, leading to results with improved accuracy. If one boundary of the averaging volume reaches the boundary of the measured volume during its expansion, it will not be evaluated at all. Reference is kept of all locations used and those not used for averaging the SAR. All average SAR values are finally assigned to the centered location in each valid averaging volume. All locations included in an averaging volume are marked to indicate that they have been used at least once. If a location has been marked as used, but has never been assigned to the center of a cube, the highest averaged SAR value of all other cubical volumes which have used this location for averaging, is assigned to this location. Only those locations that are not part of any valid averaging volume should be marked as unused. For the case of an unused location, a new averaging volume must be constructed which will have the unused location centered at one surface of the cube. The remaining five surfaces are expanded evenly in all directions until the required mass is enclosed, regardless of the amount of included air. Of the six possible cubes with one surface centered on the unused location, the smallest cube is used, which still contains the required mass.

If the final cube containing the highest averaged SAR touches the surface of the measured volume, an appropriate warning is issued within the Postprocessing engine.

Interpolation

The probe is calibrated at the center of the dipole sensors which is located 2.5mm away from the probe tip. During measurements, the probe stops shortly above the phantom surface, depending on the probe and the surface detecting system. Both distances are included as parameters in the probe configuration file. The software always knows exactly how far away the measured point is from the surface. As the probe cannot directly measure at the surface, the values between the deepest measured point and the surface must be extrapolated.

The choice of the coordinate system defining the location of the measurement points has no influence on the uncertainty of the interpolation, Maxima Search and extrapolation routines. The interpolation, extrapolation and maximum search routines are all based on the modified Quadratic Shepard's method.

Thereby, the interpolation scheme combines a least-square fitted function method and a weighted average method which are the two basic types of computational interpolation and approximation. The routines construct a once-continuously differentiable function that interpolates the

measurement values as follows:
• For each measurement point a trivariate (3-D) / bivariate (2-D) quadratic is computed.
It interpolates the measurement values at the data point and forms a least-square spline fit to neighboring measurement values.
• the spatial location of the quadratic with respect to the measurement values is attenuated by an inverse distance weighting. This is performed since the calculated quadratic will fit measurement values at nearby points more accurate than at points located further away.
• After the quatratics are calculated for at all measurement points, the interpolating function is calculated as a weighted average of the quadratics.

There are two control paramaters that govern the behavior of the interpolation method. One specifies the number of measurement points to be used in computing the least-square fits for the local quadratics. These measurement points are the ones nearest the input point for which the quadratic is being computed. The second parameter specifies the number of measurement points that will be used in calculating the weights for the quadratics to produce the final function. The input data points used there are the ones nearest the point at which the interpolation is desired. Appropriate defaults are chosen for each of the control parameters.

The trivariate quadratics that have been previously computed for the 3-D interpolation and whose input data are at the closest distance from the phantom surface, are used in order to extrapolate the fields to the surface of the phantom. In order to determine all the field maxima in 2-D (Area Scan) and 3-D (Zoom Scan), the measurement grid is refined by a default factor of 10 and the interpolation function is used to evaluate all field values between corresponding measurement points. Subsequently, a linear search is applied to find all the candidate maxima. In a last step, non physical maxima are removed and only those maxima which are within 2 dB of the global maximum value are retained.

Important: To be processable by the interpolation/extrapolation scheme, the Area Scan requires at least 6 measurement points. The Cube Scan requires at least 10 measurement points to allow a application of these algorithms.

In the Area Scan, the gradient of the interpolation function is evaluated to find all the extrema of the SAR distribution. The uncertainty on the locations of the extrema is less than 1/20 of the grid size. Only local maxima within -2 dB of the global maximum are searched and passed for the Cube Scan measurement.