III: SPECIFIC INFORMATION FOR SAR COMPUTATIONS

1) Computational resources
a) a summary of the computational resource required to perform the SAR computations for the test transmitter and phantom configurations

Response: The human body model used for these analyses is the High Fidelity Human Body Model, which is provided with the Remcom XFDTD software. MICS modeling started with a human body model obtained from REMCOM, Inc.   The software used for the computational analyses is Remcom XFDTD version 5.3.

b) a summary of the computational requirements with respect to modeling and computing parameters for determining the highest exposure expected for normal device operation, such as minimal computational requirements and those used in the computation

Response: A uniform cell size of 5 mm was used. This allowed modelling of the antenna, which is the only source of RF energy and the human body. The number of cells, in this case, was about 4 million. Experience with the 5mm model has determined that the region of maximum SAR is concentrated very near the antenna. This allowed the second analysis with 1mm model in a box of a homogeneous muscle tissue (cell space requirement of about 8.5 million cells).

2) FDTD algorithm implementation and validation
a) a summary of the basic algorithm implementation applicable to the particular SAR evaluation, including absorbing boundary conditions, source excitation methods, certain standard algorithms for handling thin metallic wires, sheets or dielectric materials etc

Response: The human body model can be used to evaluate the safety of the MICS implant by examining the Specific Absorption Rate (SAR) in the body. In general, the Finite-Difference Time-Domain (FDTD) method calculates the time-domain vector E and H fields at every location inside and outside of the body. These can be converted to frequency domain fields (magnitude and phase at given frequencies). From them, values commonly of interest in bioelectromagnetic simulations can be calculated, including SAR, current density, total power absorbed, temperature rise, etc. The analysed structure was surrounded by the Absorbing Boundary Conditions (ABC). The excitation was a sinusoidal source with the frequency 403MHz. Please see figures 7 and 8 in the main report for additional information.

b) descriptions of the procedures used to validate the basic computing algorithms described in a) and analysis of the computing accuracy based on these algorithms for the particular SAR evaluation

Response: The computing algorithm using the FDTD method has been known since 1966, when it was invented by K.S. Yee (see: Yee, K.S., "Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media", IEEE

Trans. Ant. Prop., 14(3), 302, 1966). Since that time, an extensive list of books and scientific articles appeared, describing and validating the algorithm. A detail analysis of FDTD method and its computing accuracy may be found in: Piotr Przybyszewski: "Fast finite-difference numerical techniques for the time and frequency domain solution of electromagnetic problems", Ph.D. Thesis, WETI, Technical University of Gdansk, Gdansk, Jul. 2001, available at: http://www.pg.gda.pl/mwave-mim/THESES/pip.pdf.

3) Computational parameters
a) a tabulated list of computational parameters such as cell size, domain size, time step size, tissue and device model separation from the absorbing boundaries and other essential parameters relating to the computational setup requirements for the SAR evaluation

Response: The computational parameters for both 5mm and 1mm are listed in the following table:

	Human body model	Muscle box model
Cell size	5mm	1mm
Domain size	128 x 80 x 390	212 x 232 x 172
Time step	9.629 ps	1.626 ps
Separation from the ABC	7 cells	7 cells
Excitation	sinusoidal	sinusoidal
Frequency	403 MHz	403 MHz
Number of Time Steps	1546	7730

b) a description of the procedures used to handle computation efficiency and modeling accuracy for the phantom and the test device

Response: The computations are performed using xfdtd software from Remcom. This software is widely used for solving problems of SAR exposure in the human body. Its efficiency and modeling accuracy has been demonstrated by a lot of examples in literature and at the Remcom's web page (http://www.remcom.com).

4) Phantom model implementation and validation
a) identify the source of the phantom model, its original resolution and the procedures used to code and assign tissue dielectric parameters for the SAR evaluation

Response: The phantom is the High Fidelity Human Body model from Remcom. (http://www.remcom.com/xfdtd6/HiFi.htm). It is made up of 5 mm cubical FDTD mesh cells, 23 different tissue types, and an overall mesh size of 136 x 87 x 397 cells (about 4 million cells).

b) verify the phantom model is appropriate for determining the highest exposure expected for normal device operation

Response: Here is an excerpt from "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio-frequency Electromagnetic Fields-Additional Information for

Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radio-frequency Emissions--Supplement C (Edition 97-01) to OET Bulletin 65 (Edition 97-01), December 1997," (http://www.remcom.com/pdfs/oet65c.pdf) written by Kwok Chan, Robert F. Cleveland, Jr., and David L. Means, Office of Engineering and Technology, Federal Communications Commission, Washington, D.C. 20554: *Currently, the finite-difference time-domain (FDTD) algorithm is the most widely accepted computational method for SAR modeling.... This method adapts very well to the tissue models which are usually derived from MRI or CT scans...such as those available from the visible man project.. FDTD offers great flexibility in modeling the inhomogeneous structures of anatomical tissues and organs. The FDTD method has been used in many far-field electromagnetic applications during the last three decades. With recent advances in computing technology, it has become possible to apply this method to near-field applications for evaluating handsets.*

c) describe procedures used to verify that the particular phantom model has been correctly constructed for making SAR computations, such as comparing computed and measured SAR results of a dipole source

Response: XFDTD has been extensively validated for Bio-EM calculations including prediction of SAR levels. For example, Ericsson Radio Systems has used XFDTD for calculations of input impedance, electric fields, and SAR levels for a spherical test geometry. They obtained excellent agreement with measured results as reported in "Measurements and FDTD Computations of the IEEE SCC 34 Spherical Bowl and Dipole Antenna" (http://www.remcom.com/pdfs/ericsson.pdf) by Martin Siegbahn and Christer Törnevik.

5) Tissue dielectric parameters
a) a description of the types of tissues used in the phantom models and the sources of tissue dielectric parameters used in the computations

Response: The Remcom's High Fidelity Human Body model contains the following 23 tissues:
1. skin
2. tendon, pancreas, prostate, aorta, liver, other
3. fat, yellow marrow
4. cortical bone
5. cancellous bone
6. blood
7. muscle, heart, spleen, colon, tongue
8. grey matter, cerebellum
9. white matter
10. CSF
11. sclera/cornea
12. vitreous humor
13. bladder
14. nerve

15. cartilage
16. gall bladder bile
17. thyroid
18. stomach/esophagus
19. lung
20. kidney
21. testis
22. lens
23. small intestine

b) verify that the tissue types and dielectric parameters used in the SAR computation are appropriate for determining the highest exposure expected for normal device operation

Response: The tissue types and dielectric parameters used in the High Fidelity Human Body Mesh give a high accuracy of SAR computations (see http://www.remcom.com/xfdtd6/HiFi.htm) and therefore are appropriate for determining the highest exposure expected for normal device operation.

b) a tabulated list of the dielectric parameters used in the device and phantom models

Response: The paramteters of the dielectrics used in the device and phantom models at 403 MHz are listed in the following table:

#	tissue	Relative permittivity	Conductivity [S/m]	Density [kg/m^3]
1	skin	4.195600e+001	5.620000e-001	1.125000e+003
2	tendon, pancreas, prostate, aorta, liver, other	5.094768e+001	7.438765e-001	1.151000e+003
3	fat, yellow marrow	5.068486e+000	4.414946e-002	9.430000e+002
4	cortical bone	1.359210e+001	1.083100e-001	1.850000e+003
5	cancellous bone	2.123435e+001	2.227471e-001	1.080000e+003
6	blood	5.745610e+001	1.712195e+000	1.057000e+003
7	muscle, heart, spleen, colon, tongue	6.411197e+001	9.700225e-001	1.059000e+003
8	grey matter, cerebellum	5.491914e+001	8.674561e-001	1.035500e+003
9	white matter	4.032535e+001	5.250120e-001	1.027400e+003
10	CSF	6.900903e+001	2.312195e+000	1.000000e+003
11	sclera/cornea	5.491000e+001	1.032000e+000	1.151000e+003
12	vitreous humor	6.837805e+001	1.552195e+000	1.000000e+003
13	bladder	2.189000e+001	2.692000e-001	1.132000e+003
14	nerve	3.609024e+001	4.921951e-001	1.112000e+003
15	cartilage	4.410049e+001	6.421951e-001	1.171000e+003
16	gall bladder bile	1.046200e+002	1.398000e+000	9.280000e+002
17	thyroid	5.344634e+001	9.021951e-001	1.035500e+003

18	stomach/esophagus	4.344203e+001	6.601539e-001	1.126000e+003
19	lung	3.839000e+001	2.734000e-001	5.630000e+002
20	kidney	1.174300e+002	8.893000e-001	1.147000e+003
21	testis	8.233000e+001	4.933000e-001	1.158000e+003
22	lens	1.127400e+002	7.742000e-001	1.163000e+003
23	small intestine	1.280900e+002	1.739000e+000	1.153000e+003
24	insulator	3.7	0	-

6) Transmitter model implementation and validation
a) a description of the essential features that must be modeled correctly for the particular test device model to be valid

Response: In order for the device to be modeled accurately, its shape, size, dimensions, position of the feed-point, and material properties should be preserved.

b) descriptions and illustrations showing the correspondence between the modeled test device and the actual device, with respect to shape, size, dimensions and near-field radiating characteristics 33

Response: The shape, size, dimensions, position of the feed-point, and material properties of the device were preserved during modeling. Figures 4, 5, 6 and 7 show the actual device and the model.

c) verify that the test device model is equivalent to the actual device for predicting the SAR distributions for satisfying 47 CFR §§2.907 and 2.908 of Commission Rules

Response: The test device was accurately dimensionally modeled including the antenna assembly, which is located in the implant header, and antenna drive point, which for purposes of the analysis, was considered to be located on the interface plane of the header and the implant case. A 1 mm mesh overlay was used in the computational analysis with the test device surrounded by muscle tissue. The driving point impedance and voltage level of the RF output at the antenna port was used to excite the modeled test device.

d) verify the SAR distribution at the high, middle and low channels, similar to those considered in SAR measurements for determining the highest SAR

Response: The frequency band is very narrow (1% with respect to the center frequency), which makes the difference between SAR distributions in different channels very small (below 1% in the highest SAR levels).

7) Test device positioning
a) a description of the device test positions (left, right, cheek, tilt/ear, extended and retracted etc.) used in the SAR computations

Response: The device was put in different positions in the torso. Figure 8 shows position at the right side of the torso. In addition to the modeling in the human body, the worst

case situation was analyzed, when the device was put in a homogeneous muscle box (1mm model).

c) illustrations showing the separation distances between the test device and the phantom for the tested configurations, similar to the reporting procedures used in SAR measurements

Response: The device was placed inside the phantom as shown in fig. 8.

8) Steady state termination procedures
a) a description of the criteria and procedures used to determine that sinusoidal steady state conditions have been reached throughout the computational domain for terminating the computations

Response: The computation time was set to six periods of 403MHz wave, as recommended in the software manual. The near field data was monitored to make sure that the steady state was actually reached.

b) reporting the number of time steps or sinusoidal cycles executed to reach steady state

Response: 1546 time steps for 5mm model, 7730 time steps for 1mm model.

c) a description of the expected error margin provided by the termination procedures

Response: The expected error margin is 1%.

9) Computing peak SAR from field components
a) a description of the procedures used to compute the sinusoidal steady total electric field with selected field components at each tissue location

Response: The computation of the sinusoidal steady total electric field is performed by an internal procedure of xfdtd software. It is done via simple calculations from the field at two time steps near the end of the calculations, when the transient fields are small enough. The two time steps are separated by about quarter of the wave period.

b) a description of the expected error margin provided by the algorithms used to compute the SAR at each tissue location according to the selected field components and tissue dielectric parameters

Response: A detail analysis of the error associated with computation of the electromagnetic fields using the finite-difference time-domain method may be found in: Piotr Przybyszewski: "Fast finite-difference numerical techniques for the time and frequency domain solution of electromagnetic problems", Ph.D. Thesis, WETI, Technical University of Gdansk, Gdansk, Jul. 2001, available at: http://www.pg.gda.pl/mwave-mim/THESES/pip.pdf. The expected error margin for the problem at hand should not exceed 1%.

10) One-gram averaged SAR procedures
a) a description of the procedures used to search for the highest one-gram averaged SAR, including the procedures for handling inhomogeneous tissues within the one-gram cube

Response: Searching for the highest one-gram averaged SAR and handling inhomogeneous tissues within one-gram cube are performed by the internal procedures of xfdtd software (http://www.remcom.com).

b) specify the weight and dimensions of the one-gram cube of tissue

Response: The weight of one-gram cube of tissue is 1 g = 1e-3 kg. The dimensions of such cube depend on the tissue and may be easily calculated from the tissue density (response 5b):
   cube_edge = (cube_weight / tissue_density)^(1/3)
For the muscle tissue, this gives a cube of the edge 0.981cm (about 2 x 5mm cells (8 cubes)).

c) a description of the expected error margin provided by the algorithms used in computing the one-gram SAR

Response: Assuming a staircase algorithm, which would use 1.000cm muscle cubes in place of 0.981cm muscle cubes, the error of computing the one-gram SAR would not exceed 6%. However, a better algorithm for one-gram SAR averaging is implemented in xfdtd, and this significantly reduces this error.

11) Total computational uncertainty – a description of the expected error and computational uncertainty for the test device and tissue models, test configurations and numerical algorithms etc.

Response: With a very pessimistic estimation of the total error, it should not exceed 8%.

12) Test results for determining SAR compliance
a) illustrations showing the SAR distribution of dominant peak locations produced by the test transmitter, with respect to the phantom and the test device, similar to those reported in SAR measurements

Response: N/A – SAR measurements were not performed.

b) a description of how the maximum device output rating is determined and used to normalized the SAR values for each test configuration

Response: The devices are tuned during production, and the output power will not exceed 0dBm.

c) a description of the procedures used to compute source-based time-averaged SAR

Response: The SAR is calculated from the electric field using equation presented at page 6. The electric field components used in this equation represent the values averaged over time. For the sinusoidal fields, the average value of the square of an electric field component is a half of the square of the magnitude of this component.