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UHF Handset Monopole Antenna Designed for SAR Compliance

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UHF Handset Monopole Antenna Designed for SAR Compliance

A Radio-Independent

Virtual Testbench and Design Flow

for pre-Prototype SAR Compliance

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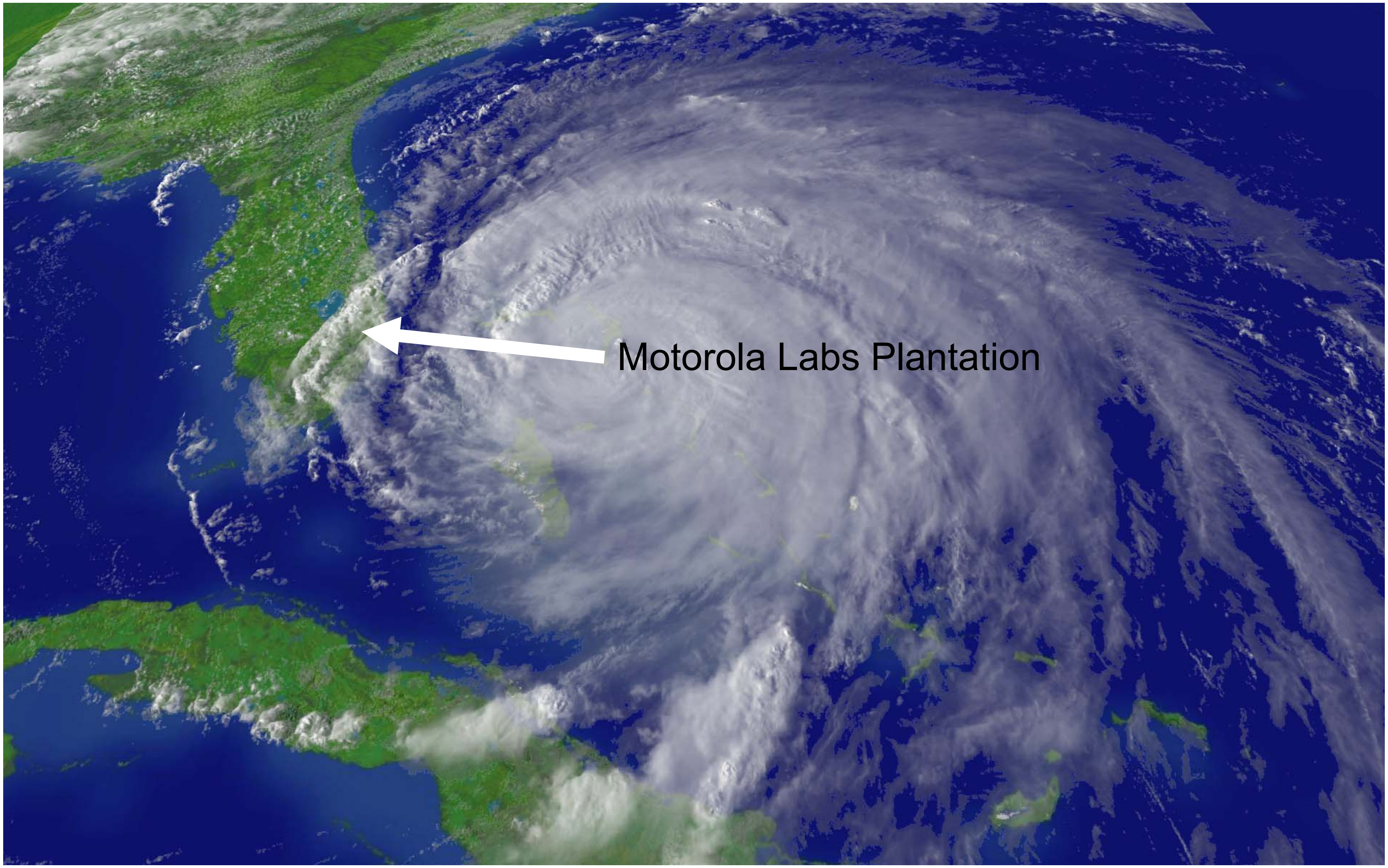

High Power Public Safety Radio

- **Target Products are …**

Hand held


Radio! Not cell phone!
OWN IT
ON DVD AND VIDEO
MARCH 8
JOHN TRAVOLTA
JOAQUIN PHOENIX
LADDER
49

Waist mounted

Radio! Not cell phone!

Specific Absorption Rate Prediction

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- **Products must show SAR compliance before commercial shipments.**
- **Design for Compliance:**
  - **early prediction of SAR characteristics ensures compliance without time consuming design-test iterations**
  - **early prediction of SAR issues ensures compliance through cost-effective pre-prototype platform/antenna changes**
- **SAR compliance limit for occupational environment 8W/kg (*general public* 1.6 W/kg)**
- **SAR is scalable by the transmitted power.**
  - **for a specific frequency with a given platform/antenna**
- **FDTD is a popular tool for SAR assessment.**

Radio SAR "Virtual Testbench"

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Purposes of presentation:

- Demonstrate the practical application of "Virtual Testbench" to assess SAR during design.
- Testbench is radio-independent
  - simply add a different platform and/or antenna
- Testbench is parametric and scalable.
- Dielectric constant and conductivity of human tissue are set according to IEEE 1528 specifications.
- Current radio is UHF, 403 MHz to 470 MHz.

Why HFSS?

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- Proven
- Handles low frequencies and 2D structure with ease
- Inherently parametric design environment
  - parametric solid models
  - optimization and parametric analyses
- Mesh controls available
  - surface approximation, aspect ratio
- Analysis setup/control easily modified
- Frequency-dependent maximum average SAR easily determined throughout entire tissue volume
- One package for both antenna development and SAR assessment

SAR calculations using HFSS

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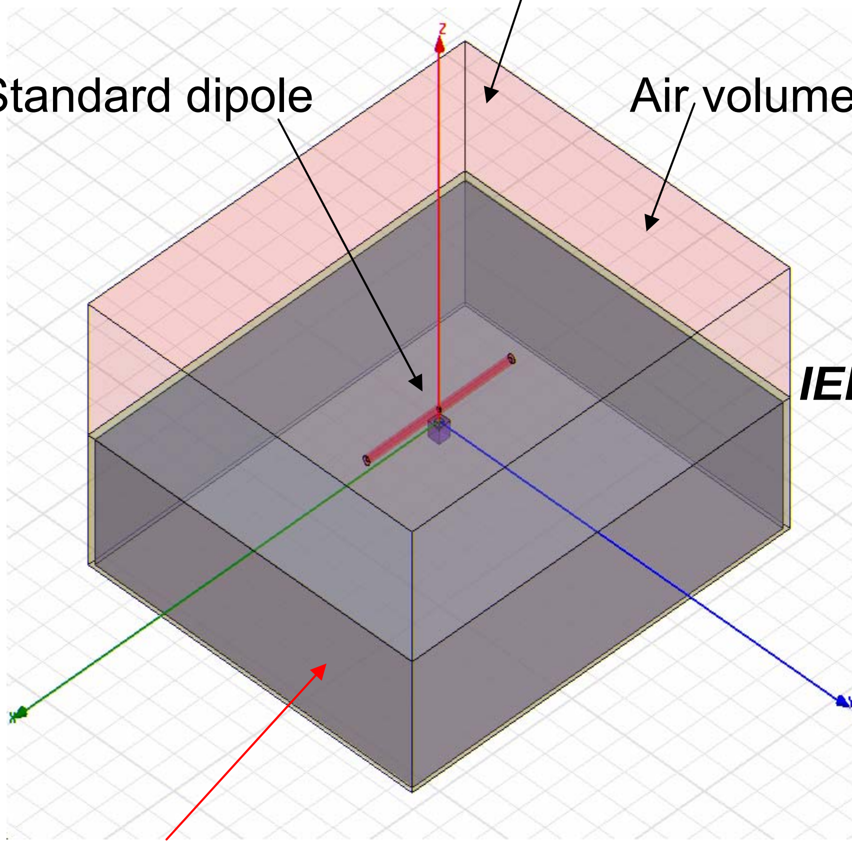
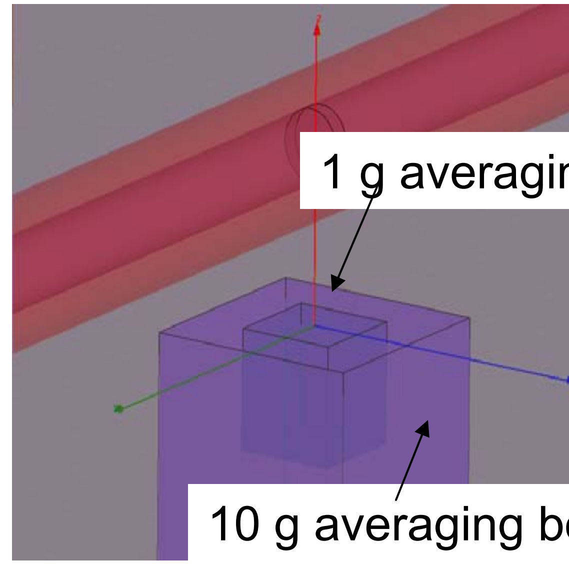
- **IEEE 1528 Calibration standards were reproduced using HFSS 9.2. (Matt Commens) for the Dipole and Phantom Model. Measured data in parenthesis.**

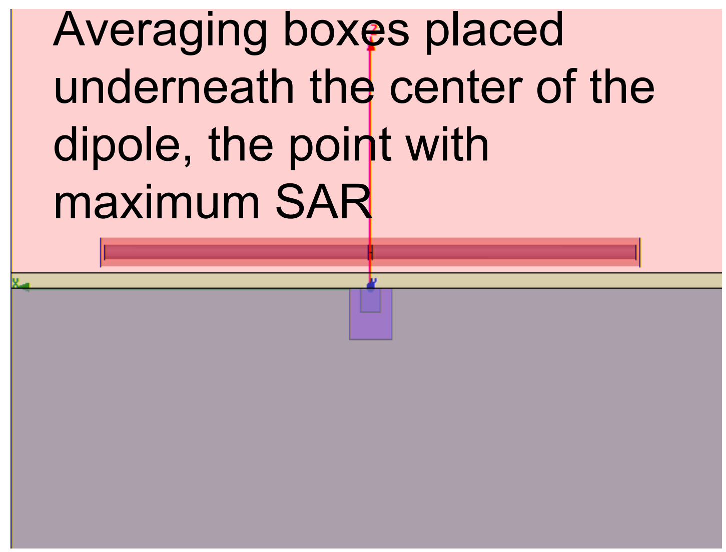
Frequency (MHz)	1g SAR	10g SAR	Local SAR at surface (above feedpoint)	Local SAR at surface (y= 2cm offset from feedpoint)
300	3.06 (3.0)	2.07 (2.0)	4.63 (4.4)	2.20 (2.1)
450	4.98 (4.9)	3.31 (3.3)	7.59 (7.2)	3.28 (3.2)
835	9.62 (9.5)	6.26 (6.2)	14.71 (14.1)	4.93 (4.9)
900	10.98 (10.8)	7.02 (6.9)	17.01 (16.4)	5.47 (5.4)
1450	29.83 (29.0)	16.50 (16.0)	53.90 (50.2)	6.54 (6.5)
1800	39.36 (38.1)	20.45 (19.8)	74.39 (69.5)	6.85 (6.8)
1900	40.97 (39.7)	21.21 (20.5)	78.02 (72.1)	6.54 (6.6)
2450	55.42 (52.4)	25.42 (24.0)	115 (104.2)	8.09 (7.7)
3000	65.81 (63.8)	26.48 (25.7)	157.66 (140.2)	8.8 (9.5)

Dipole and Phantom Testbench



IEEE 1528





Specifying 1g SAR calculation

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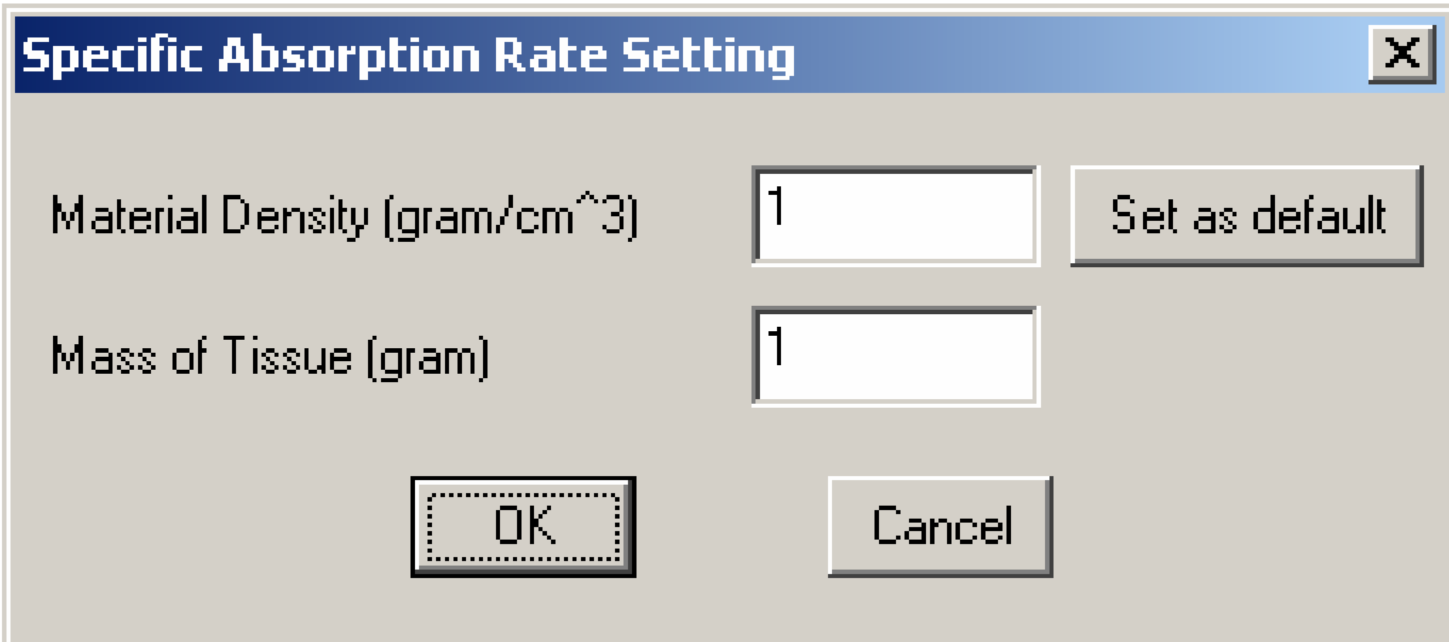

Averaging 1g SAR in a cube with the volume of $1cm^3$
A $1cm^3$ averaging box is used.

"Virtual Testbench" with a generic Radio for SAR prediction in UHF band

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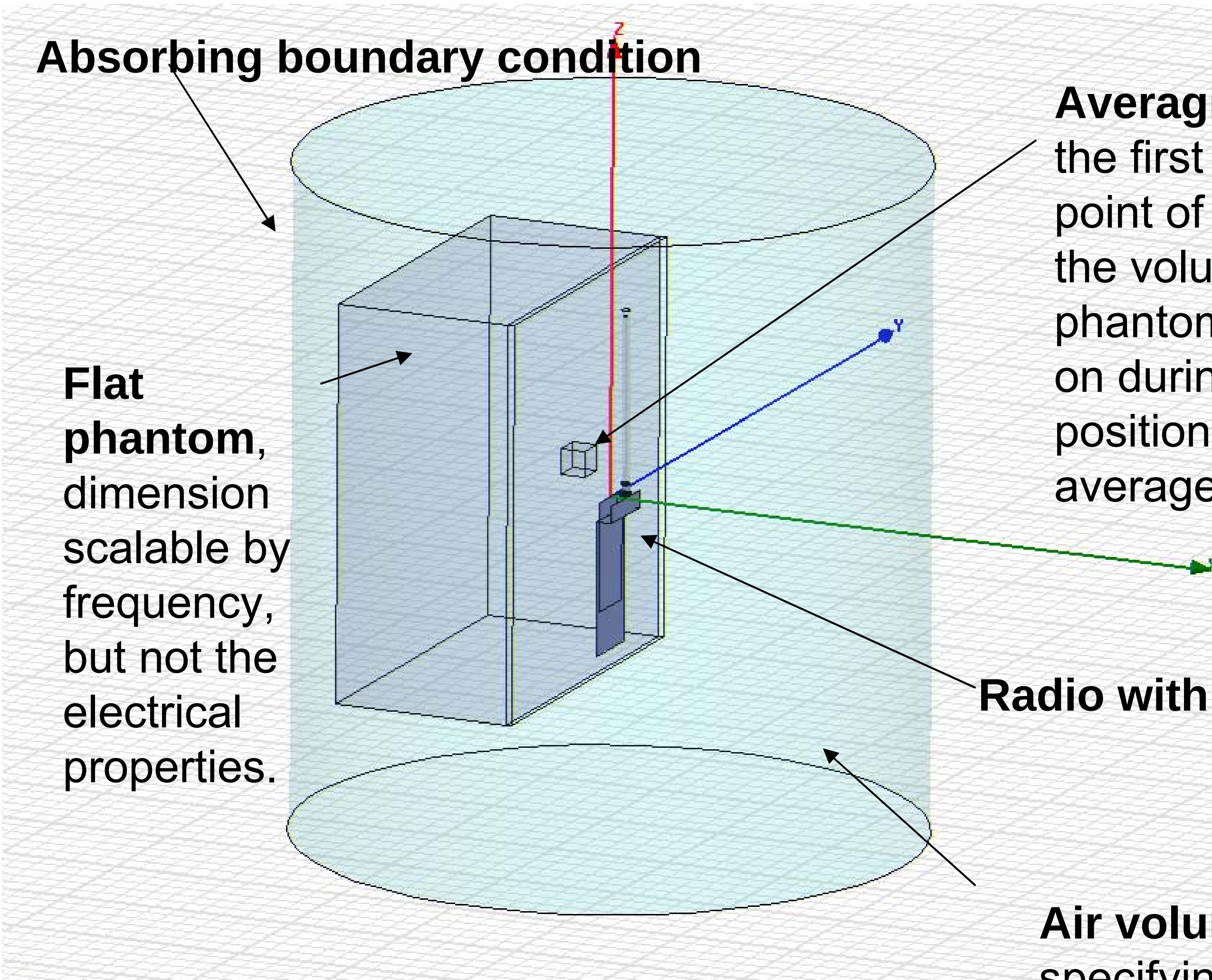

Design parameters

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Ho_outerbraid	101	mm
Ho_moulding	108	mm
lowest_freq	400	MHz
max_wavelenth	3e8 /lowest_freq	
airboxradius	max_wavelenth/3	
airboxheight	0.6*max_wavelenth	
box10gside	21.54	mm
d_phantom	150	mm
w_phantom	0.4*max_wavelenth	
l_phantom	0.6*max_wavelenth	
maxsar_y_offset	12	mm
maxsar_z_offset	10	mm
monopole_length	165	mm
maxSARX	-38.5	mm
maxSARy	11.05	mm
maxSARz	7.391	mm

Add... Remove

Input frequency information

Air box size is set.

Phantom width 0.4 wavelength
length 0.6 wavelength

Tuning the length of the antenna

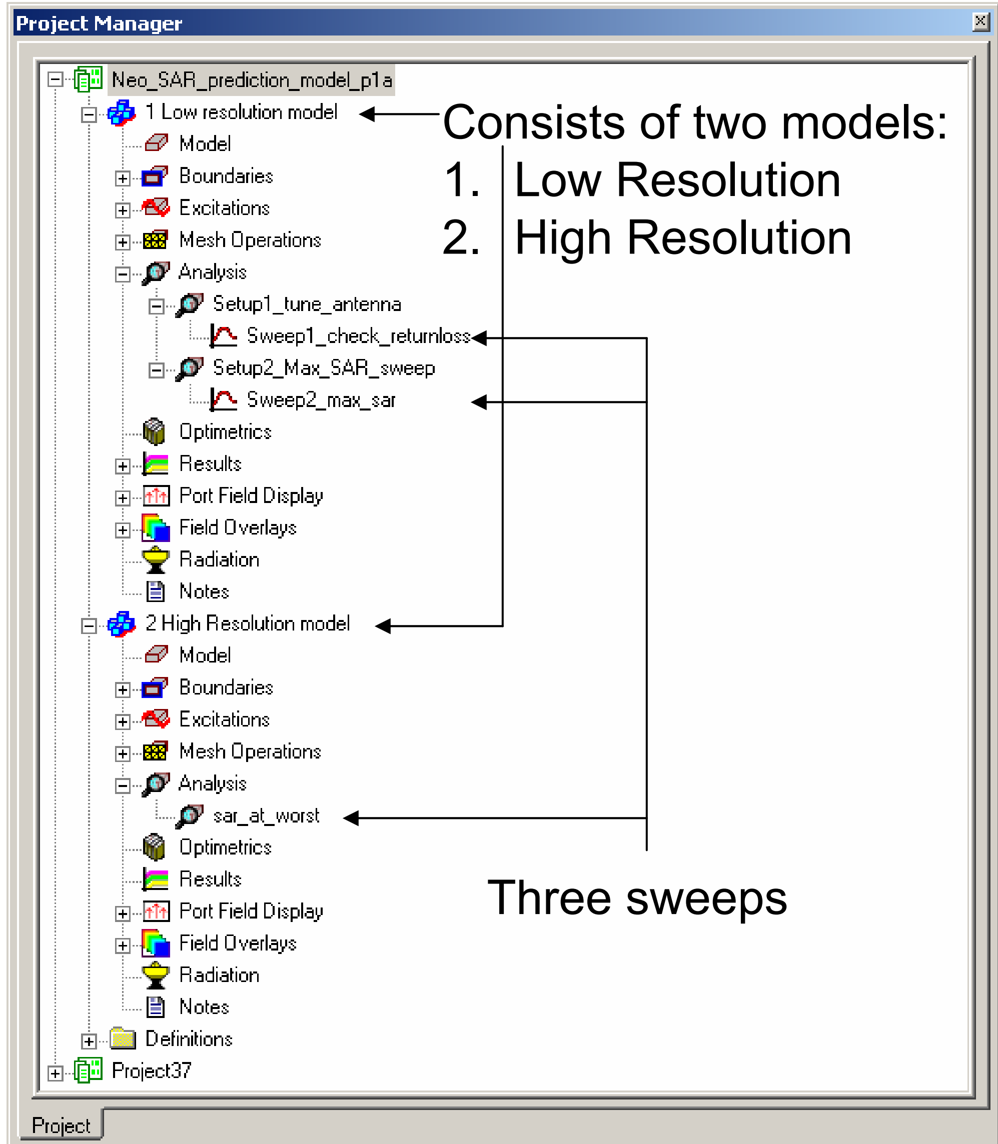
Position of maximum SAR

SAR assessment Design Flow with HFSS based “Virtual Testbench”

1. Rapid ***Interpolating Sweep***:
   Verify/tune radiation and circuit behavior of antenna and/or platform, max delta-S11=0.05.

2. Accurate ***Fast Sweep***:
   Saves fields over frequency and volume to determine frequency and location of max-avg-SAR.

3. Highly Accurate ***Single Frequency***:
   Frequency for max-avg-SAR.
   Averaging box placed at location of max-avg-SAR.
   Reduced delta-S for high accuracy.



Design Phase 1: Lower resolution analysis with *INTERPOLATING* frequency sweep

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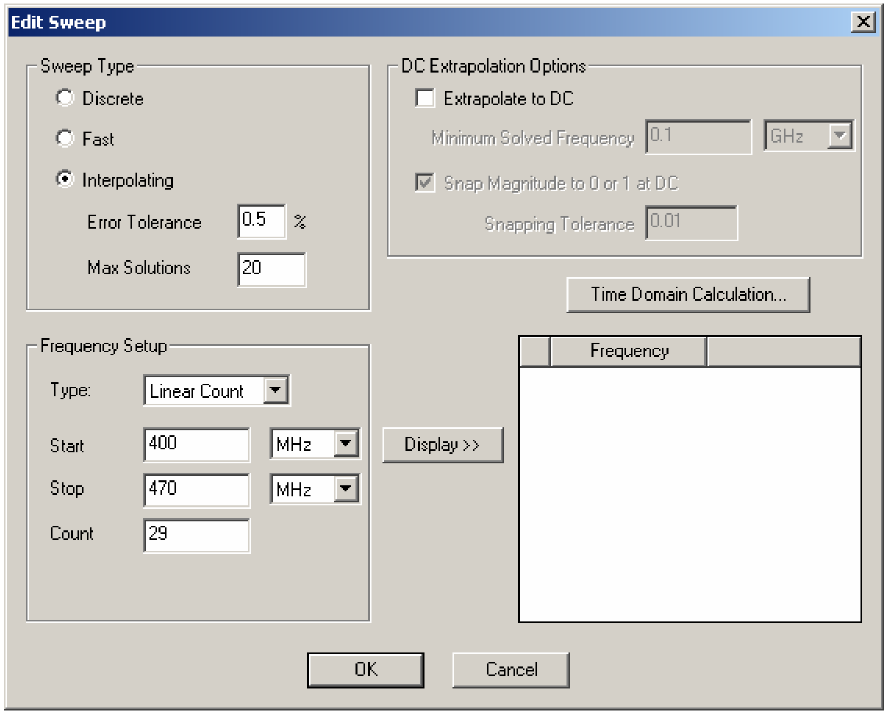
- **Lower Resolution Analysis**
  - **less strict convergence criteria**
  - **faster analysis time**
  - **broader frequency range**
- **Fields not necessarily saved**
  - **circuit behavior verified**
  - **radiation behavior may be examined for saved fields**
- **Tuning of Radio**
  - **to adjust circuit or radiation response for platform/antenna combination**
  - **to compensate for presence of tissue**



Design Phase 2: Lower resolution analysis with *FAST* frequency sweep

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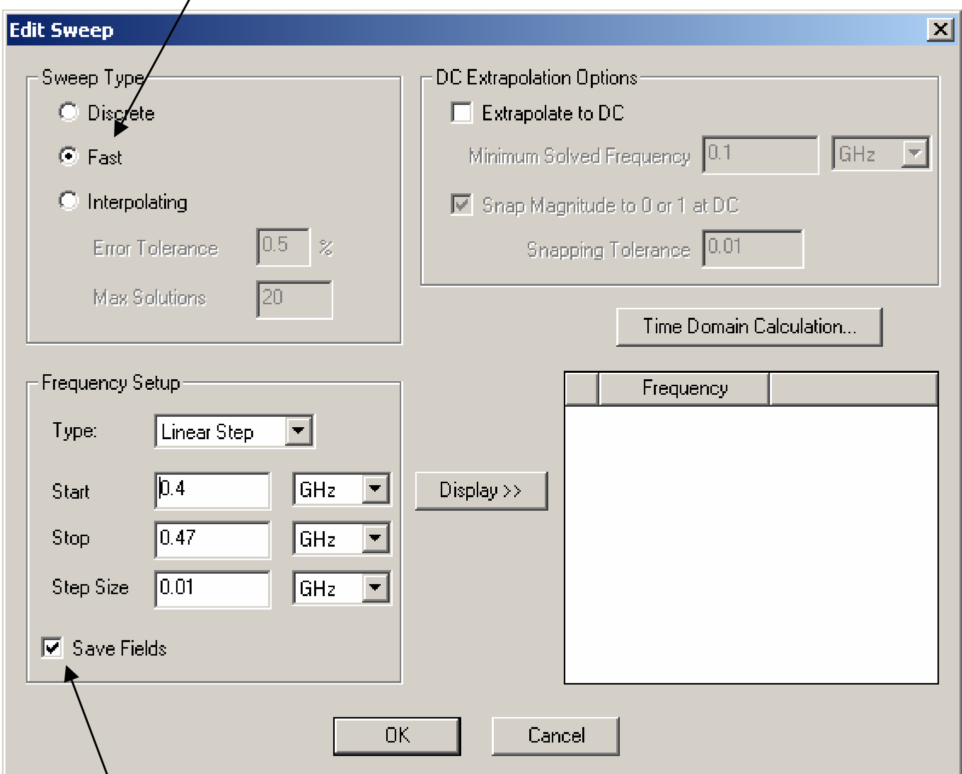
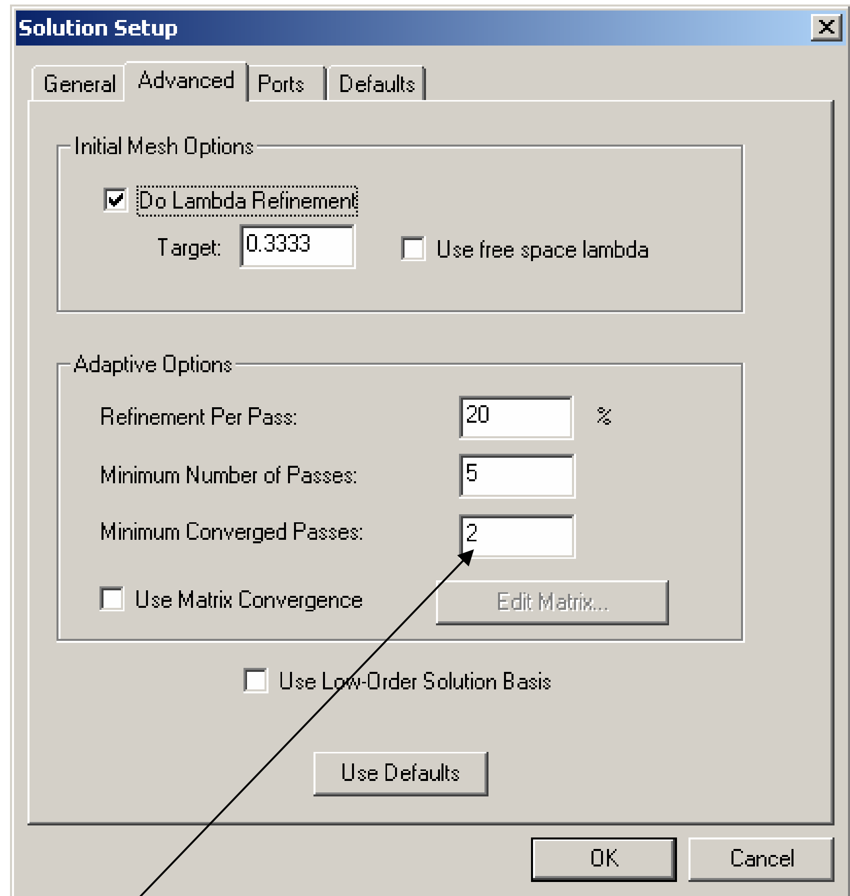
Fast Sweep

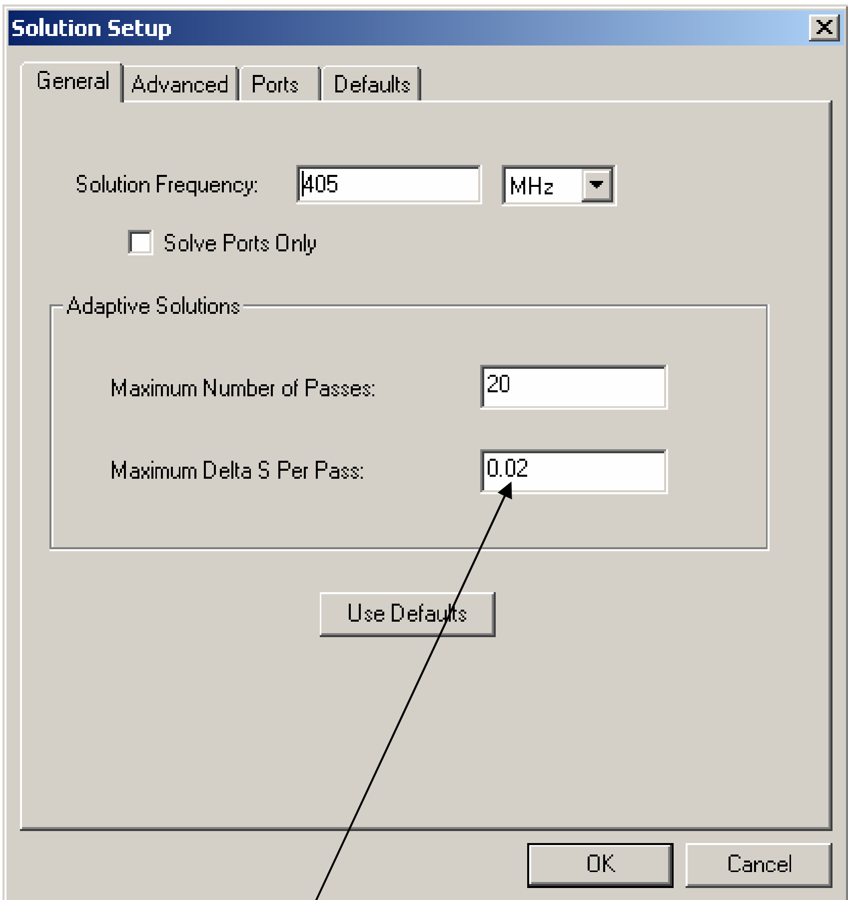


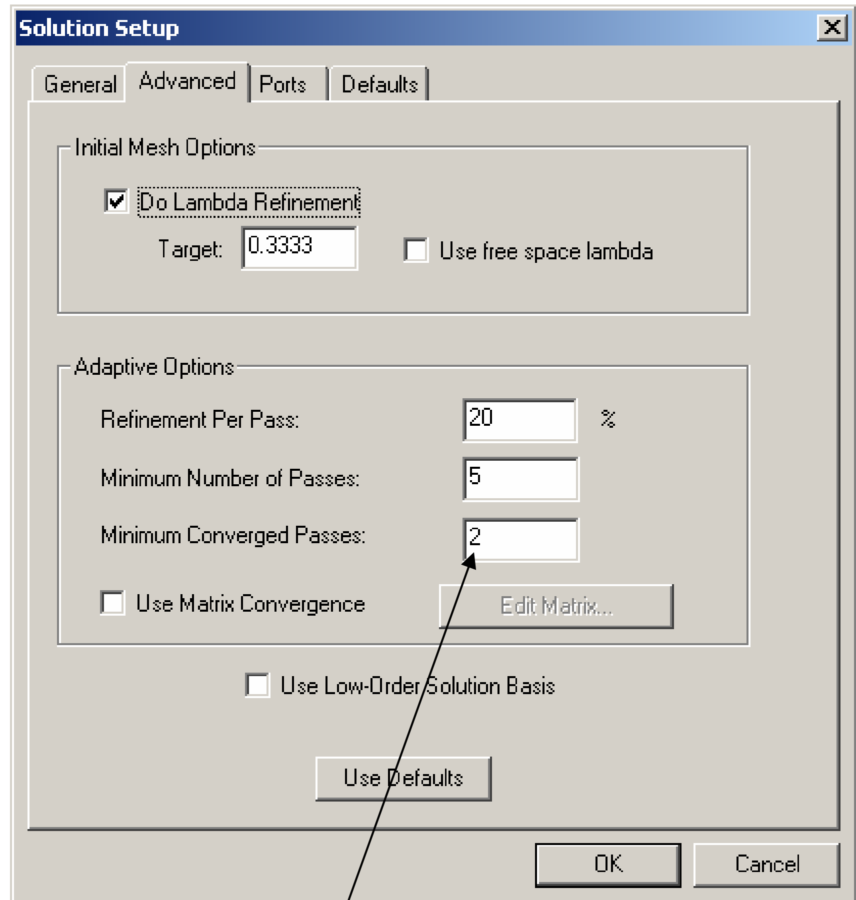


Save field

Two consecutive converged passes

Design Phase 3: Higher resolution analysis with no frequency sweep

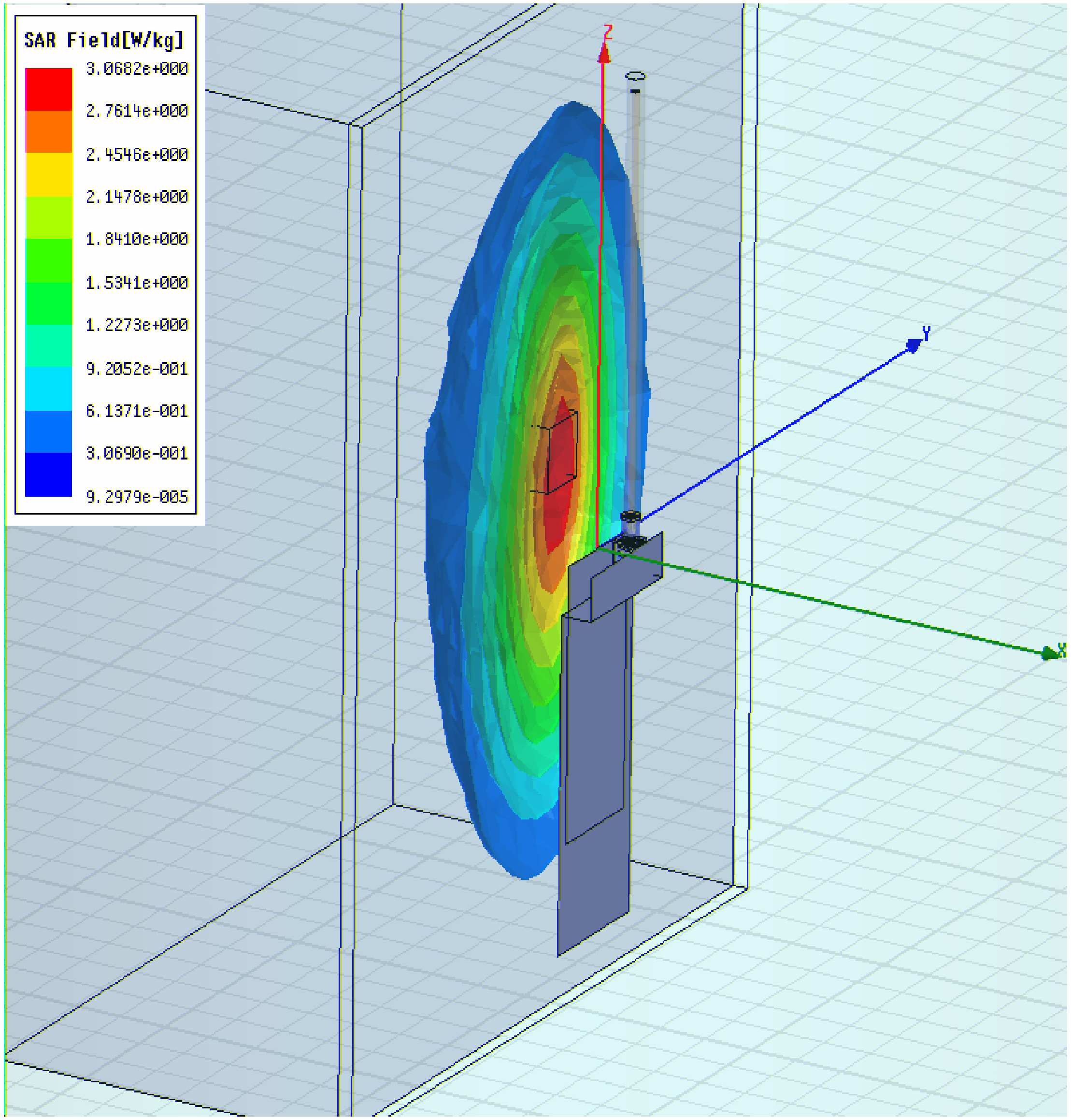




Smaller delta-S

Two consecutive converged passes

Typical SAR plot



Create a saved expression for SAR using the HFSS field calculator

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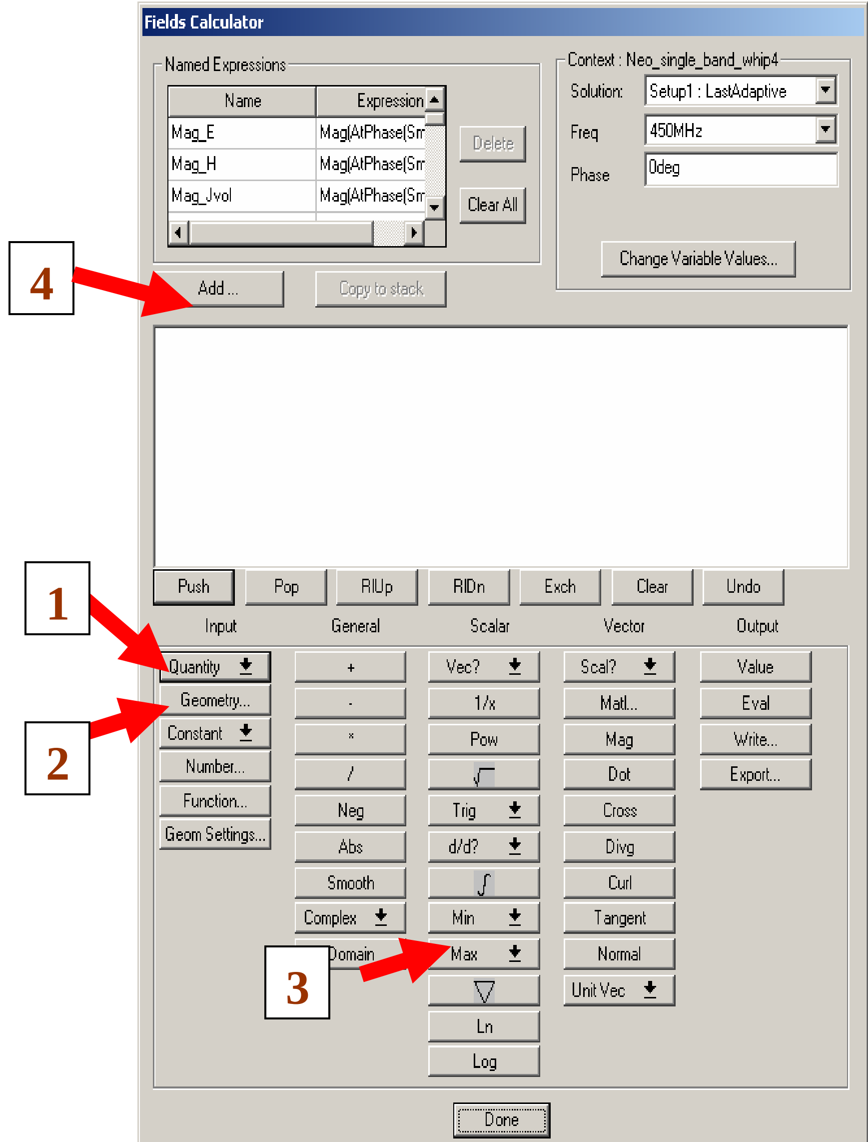
1. Click on Quantity and choose AverageSAR

2. Click on Geometry and select ***tissue***, or any other volume you would like to have your SAR calculated then click OK.

3. Click Maximum and choose value.

4. Click add and assign a name to it, e.g. ***maxsar***



Create an output variable for SAR

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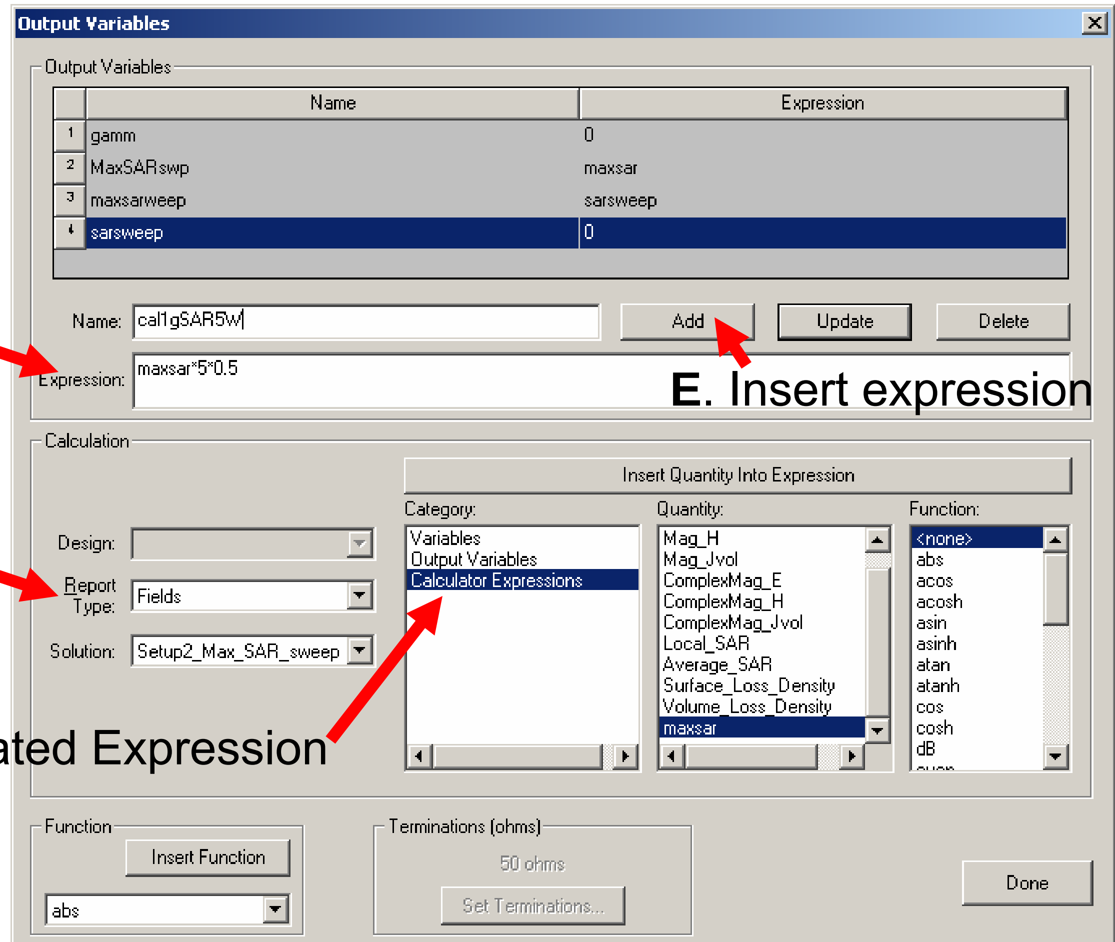
NOTE:
Calculated SAR is normalized to 1W. Must scale the SAR to actual power and adjust for duty cycle.

D. Edit expression
Cal1gSAR5W=maxsar*5*0.5
(5 W power and 50% duty cycle)

E. Insert expression

A. Select Fields

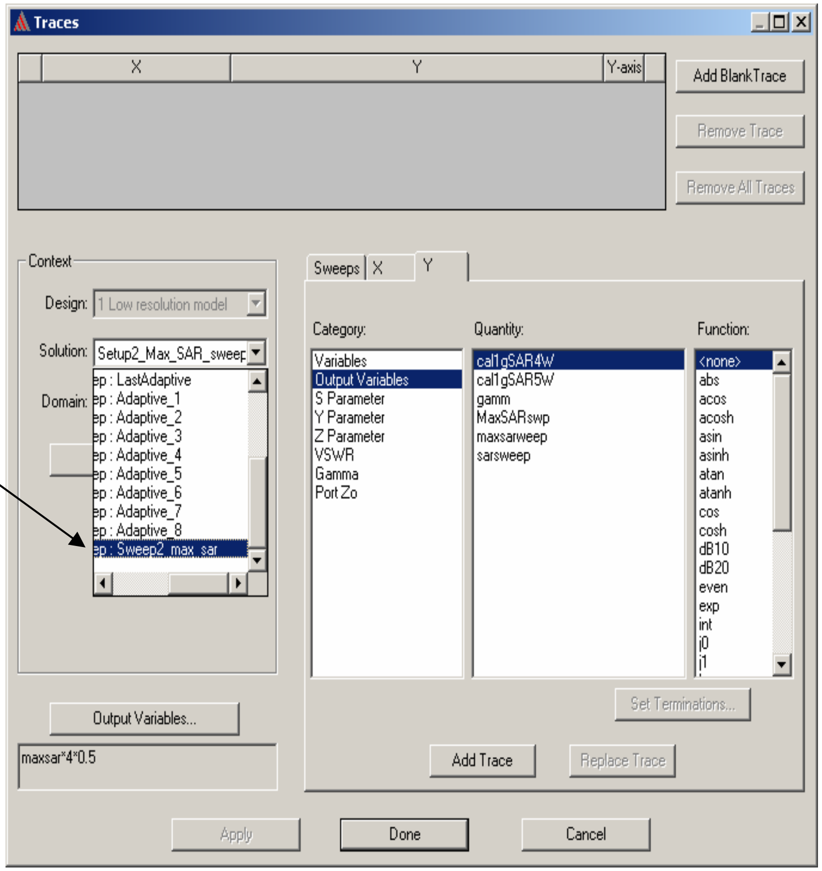
B. Calculated Expression



C. Select the variable

Design Stage 2: Plotting Max Cal 1g SAR

Assure the fast frequency sweep is selected.

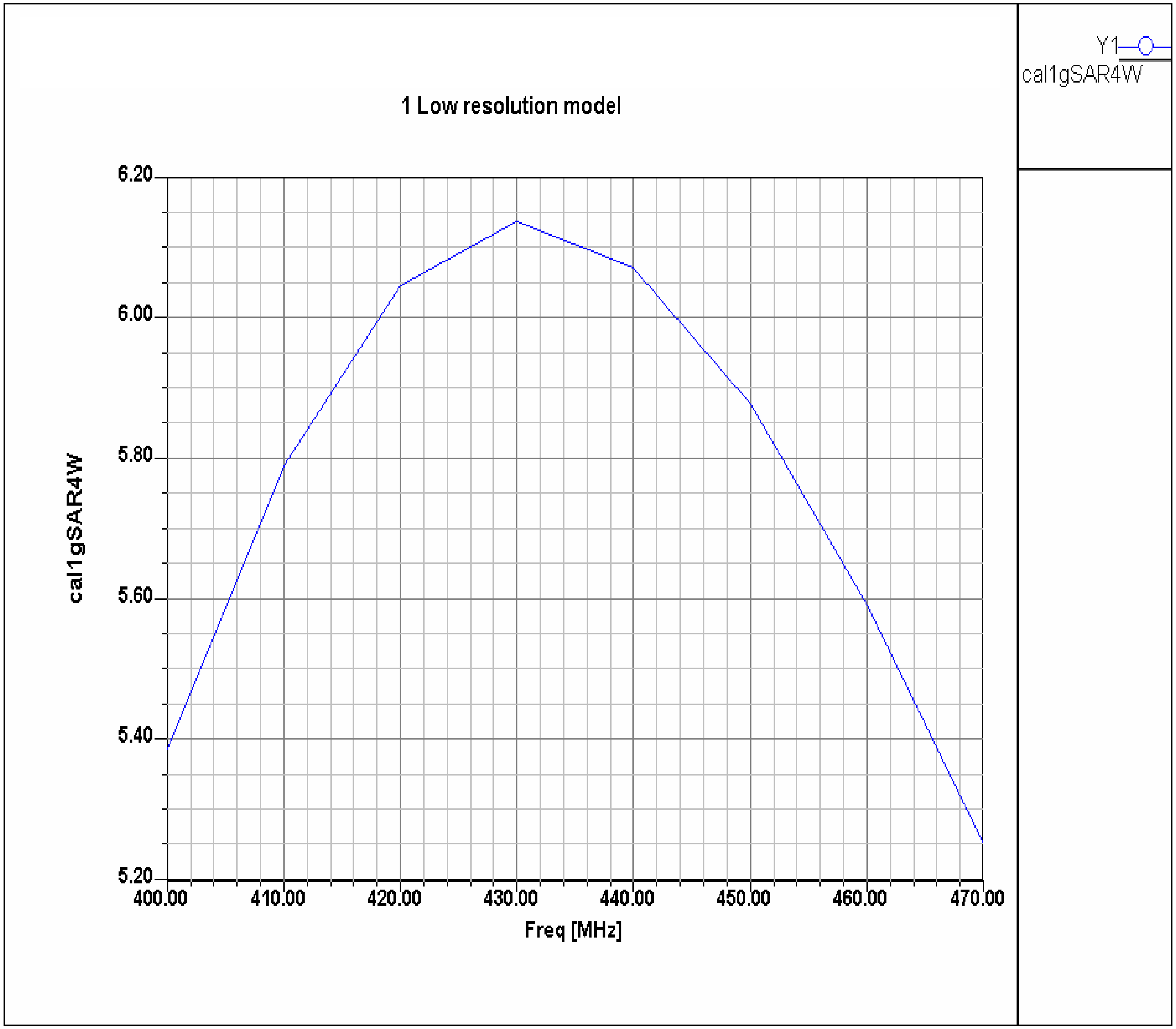


NOTE:

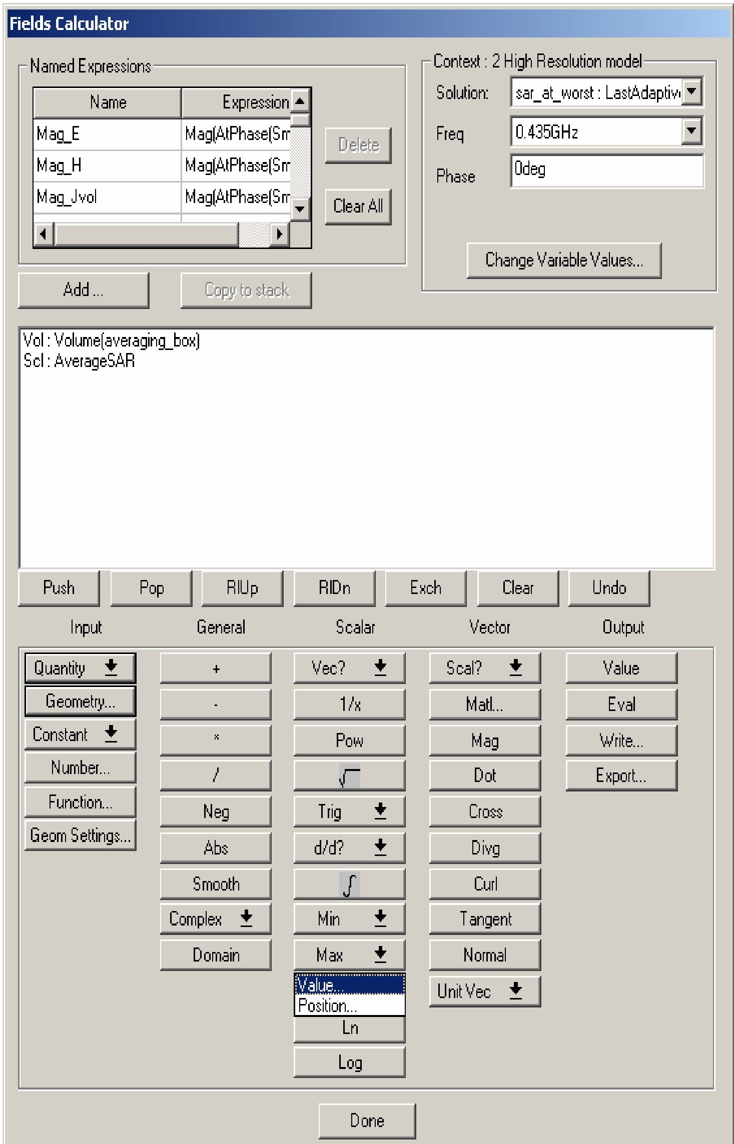
HFSS automatically computes the field calculator saved expression and plots the corresponding output variable as a function of frequency.

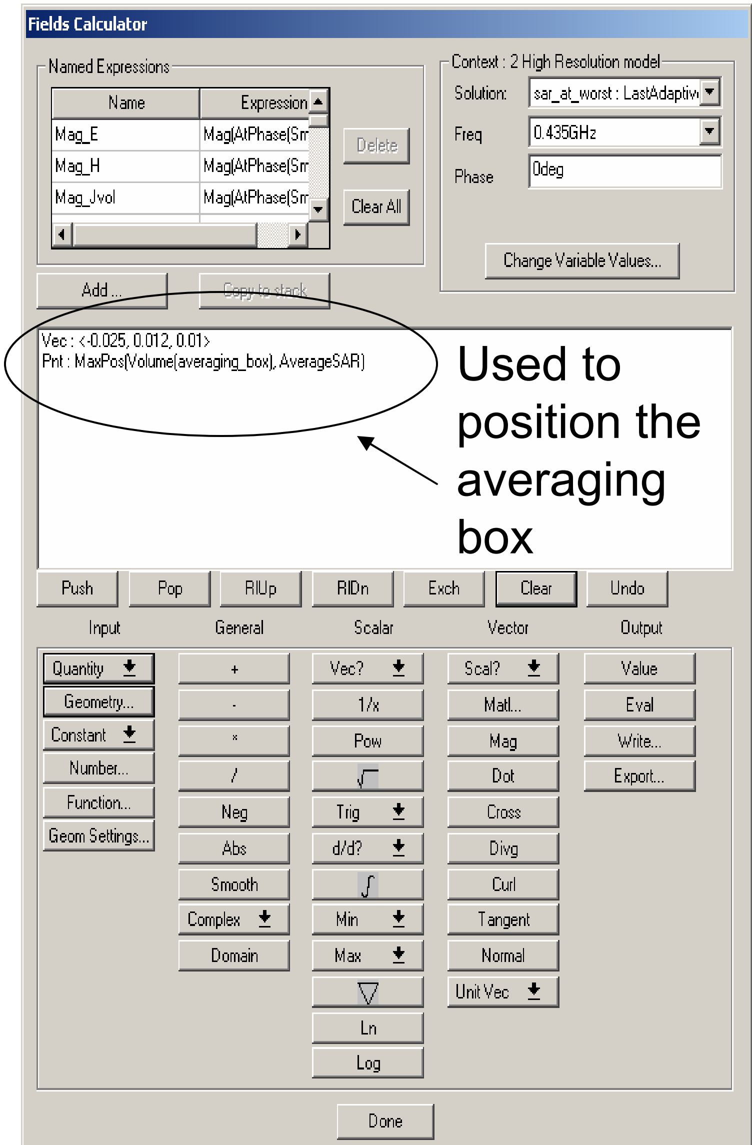
These computations may be time consuming so specify a reasonable number of frequencies (≈10, not ≈100).

Design Stage 2: Plot of Max 1g SAR Scaled to 4 W



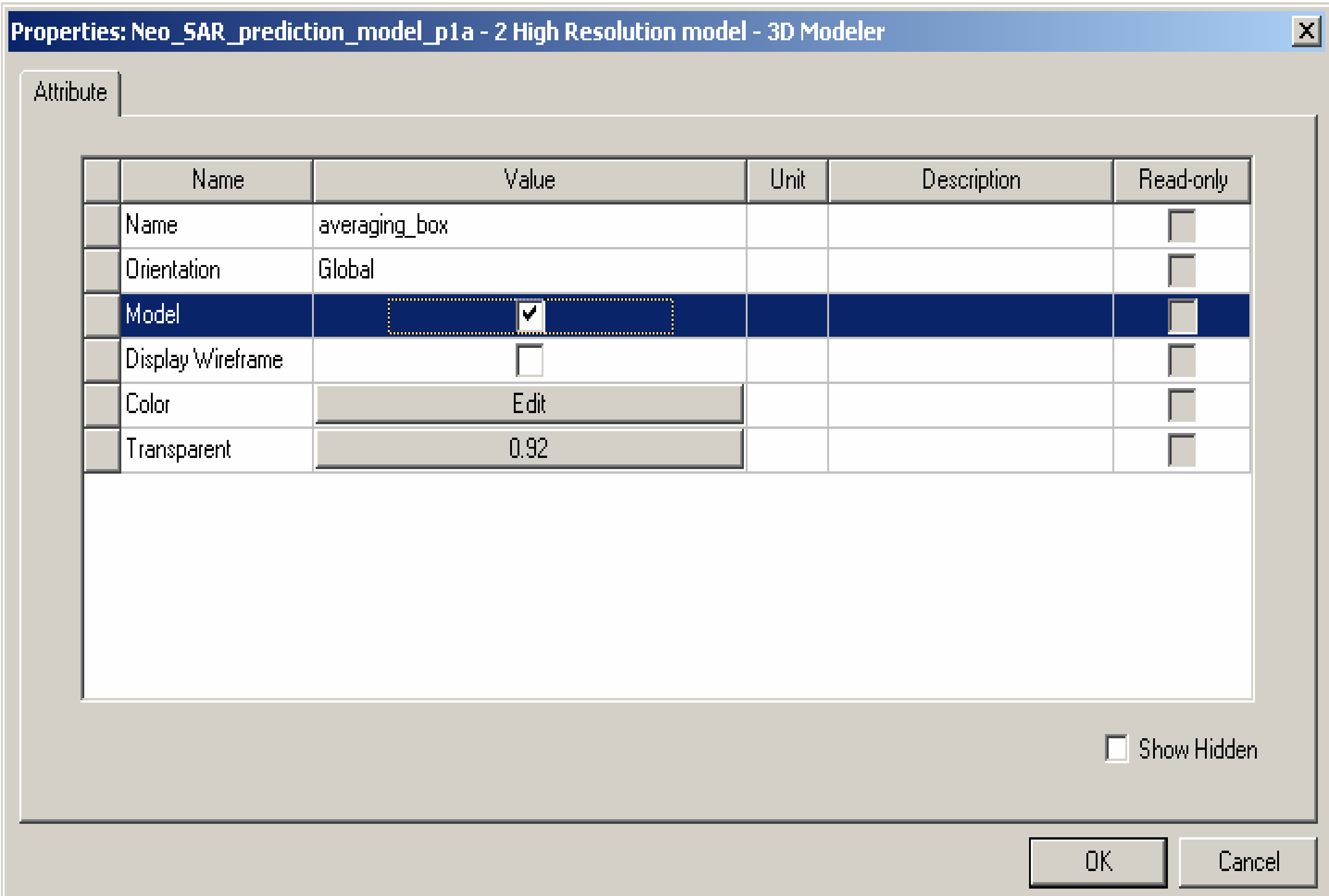
Design Stage 2: Obtain Max Average SAR and its Position





Design Stage 3: Add the averaging box to the high resolution design setup

Create the high resolution model by duplicating the low resolution model and turned on the averaging box. Analyzing at the worst case frequency found earlier.



Design Stage 3: Extract the Maximum Average SAR in the tissue volume

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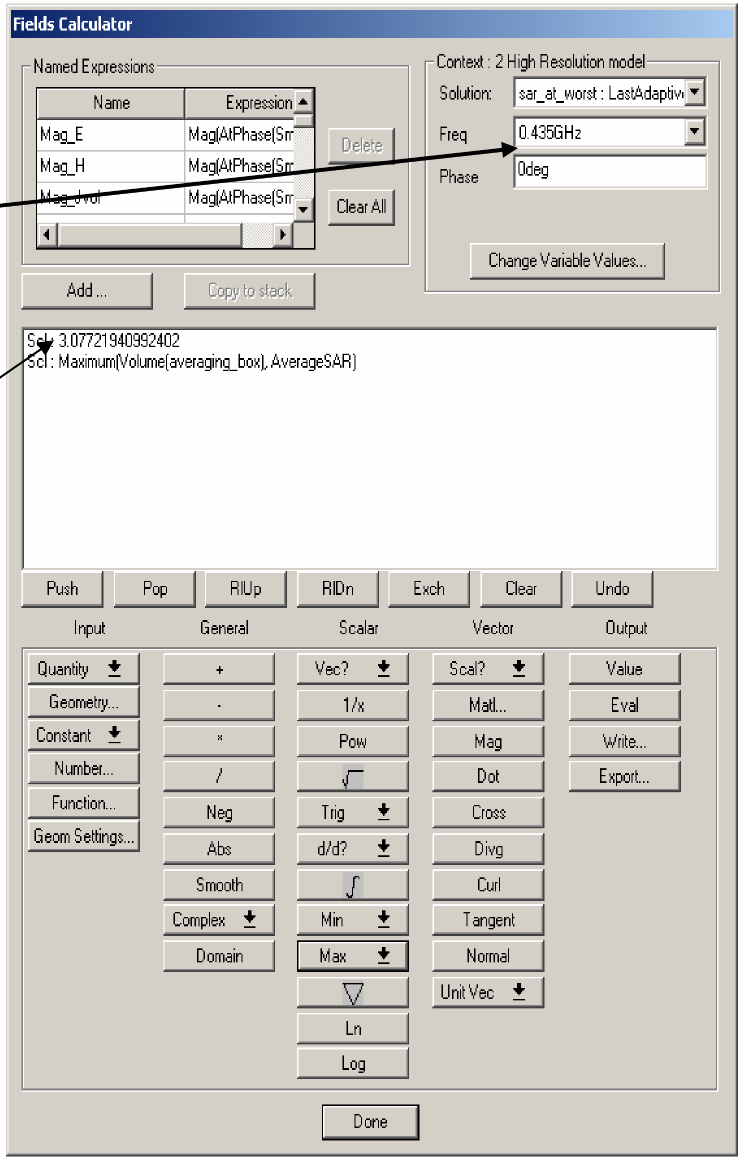
The worst case frequency, as determined in Stage 2.

The Max Average SAR, calculation shown previously.



Technology Transfer

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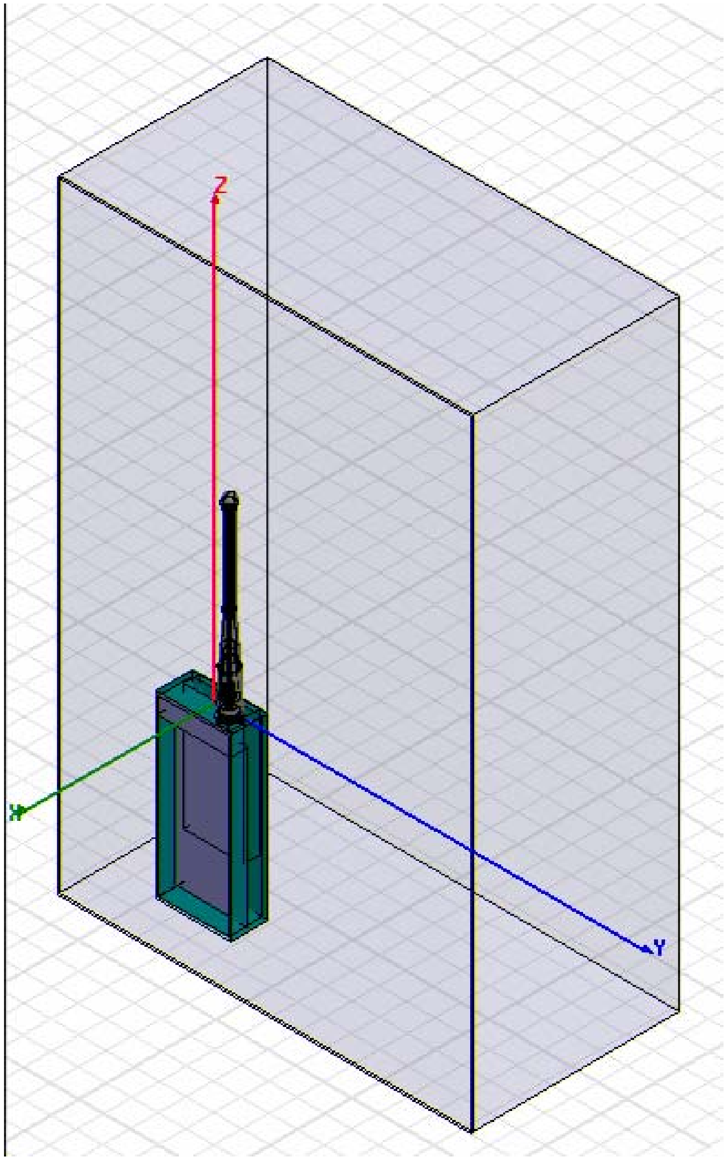
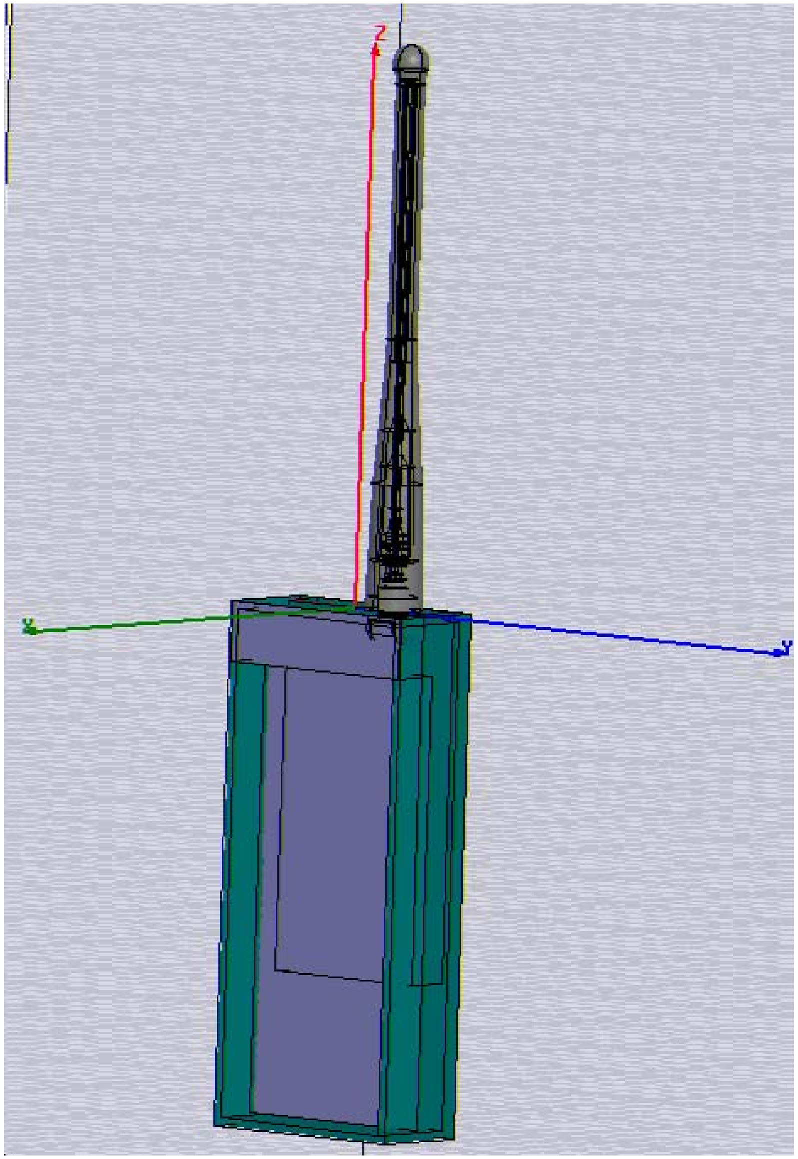
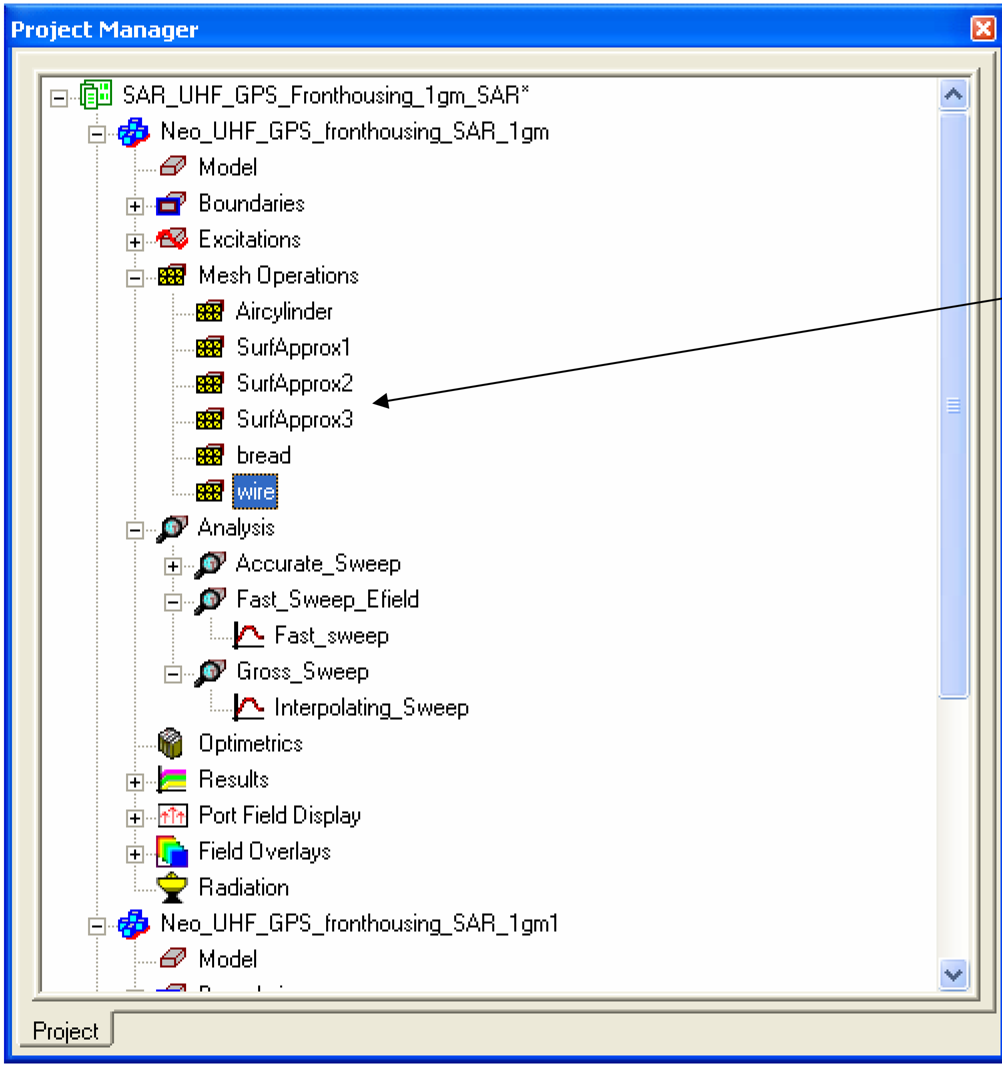
- **The "Virtual Testbench" and companion design flow were verified with a generic radio and then passed to the Product Development group.**
- **The Antenna was replaced with a monopole of interest.**
- **The radio platform was replaced with the actual chassis, including the front housing.**
  - **solid model was imported to HFSS from Pro/E.**
  - **solid model was simplified**
  - **surface approximation was used to simplify the mesh.**
- **The antenna went through a few iterations of design change before finalization.**

UHF Radio Solid Model in HFSS



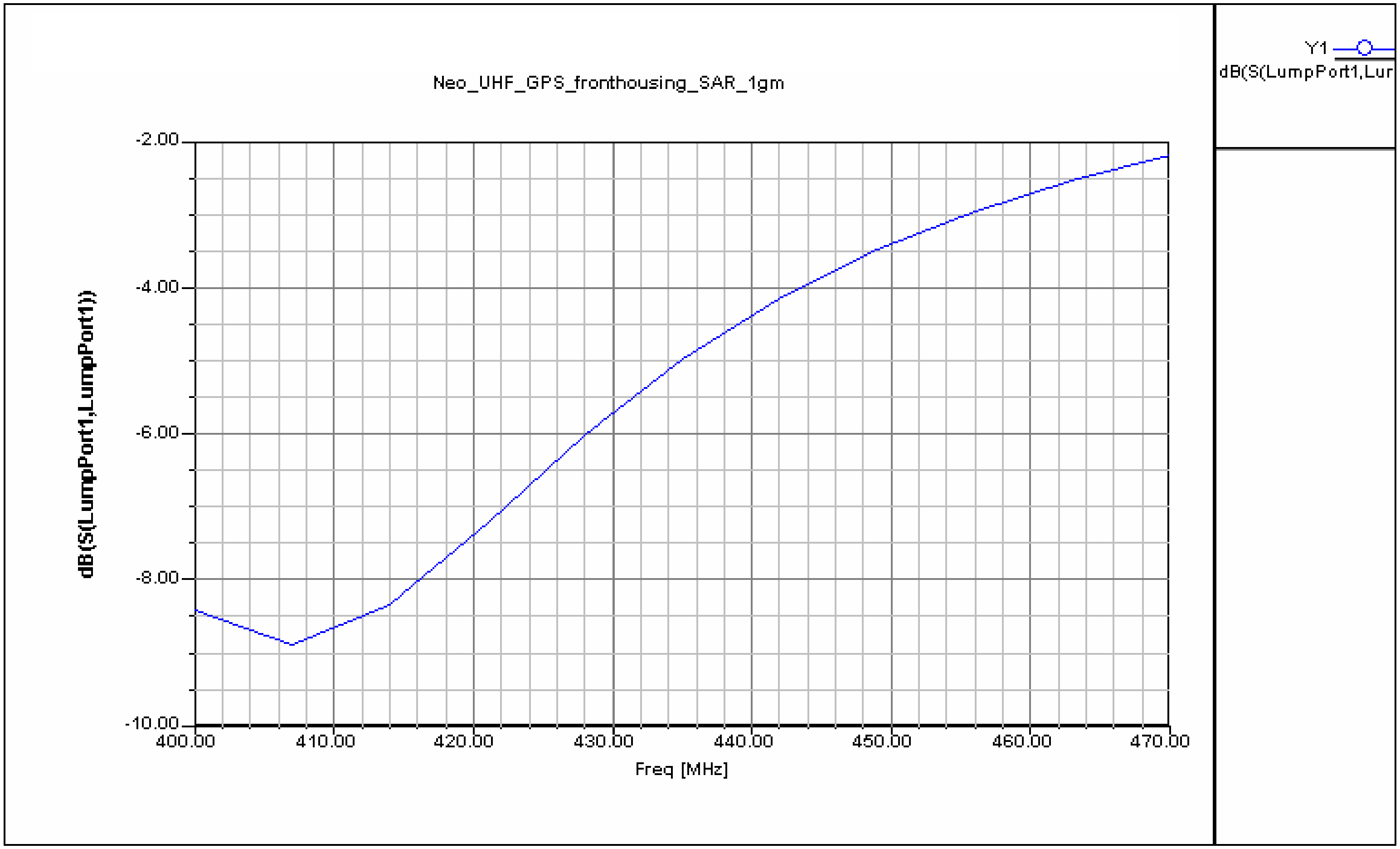


Surface approximation for cylindrical parts

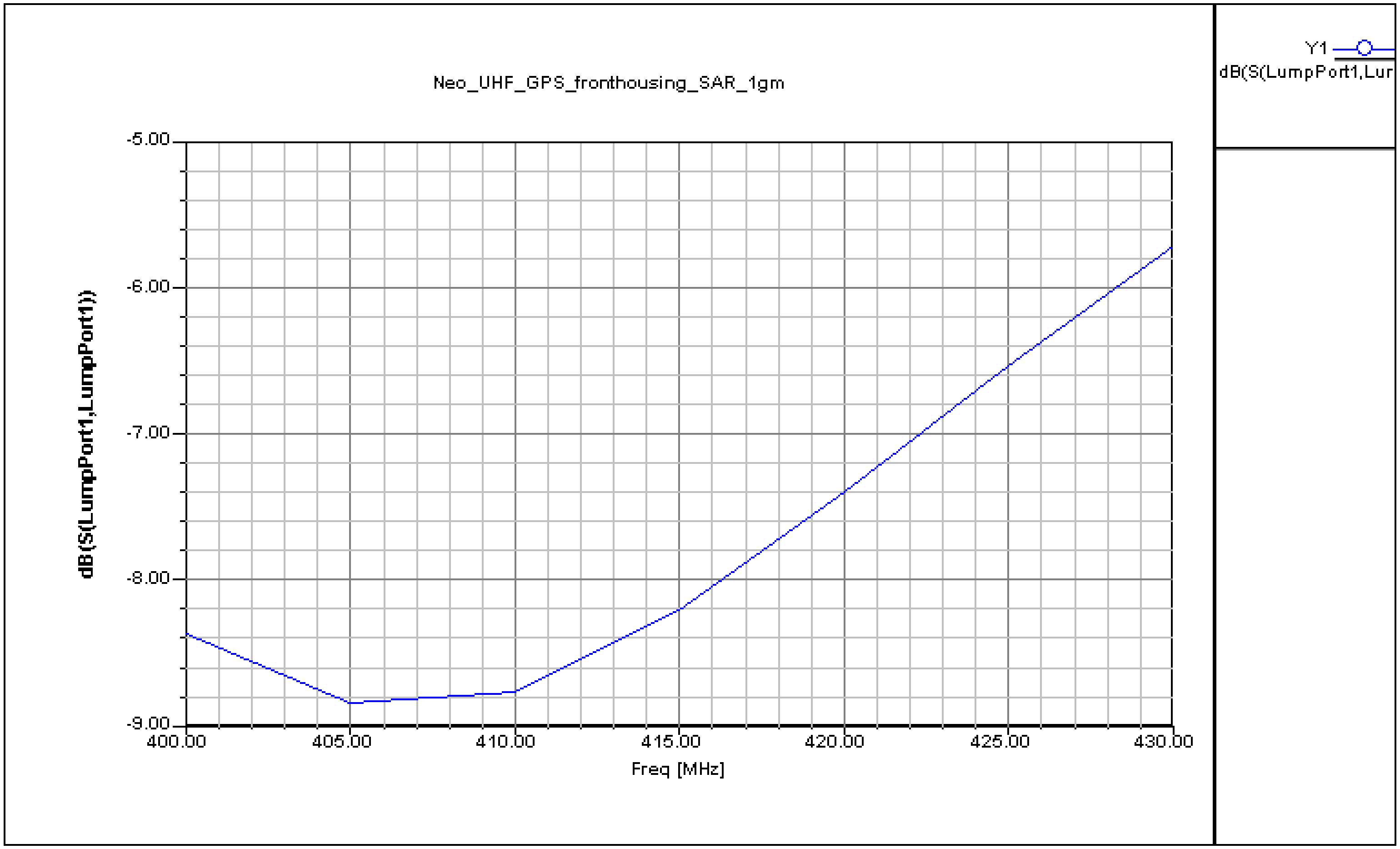


All cylindrical parts were assigned maximum of 45 degree deviation angle as circular surface approximation.

Design Stage 1: Return loss of UHF Monopole Antenna *(interpolating sweep)*



Design Stage 2: Return loss of UHF Monopole Antenna *(fast sweep)*



Design Stage 2: Frequency-dependent Max Average 1g SAR

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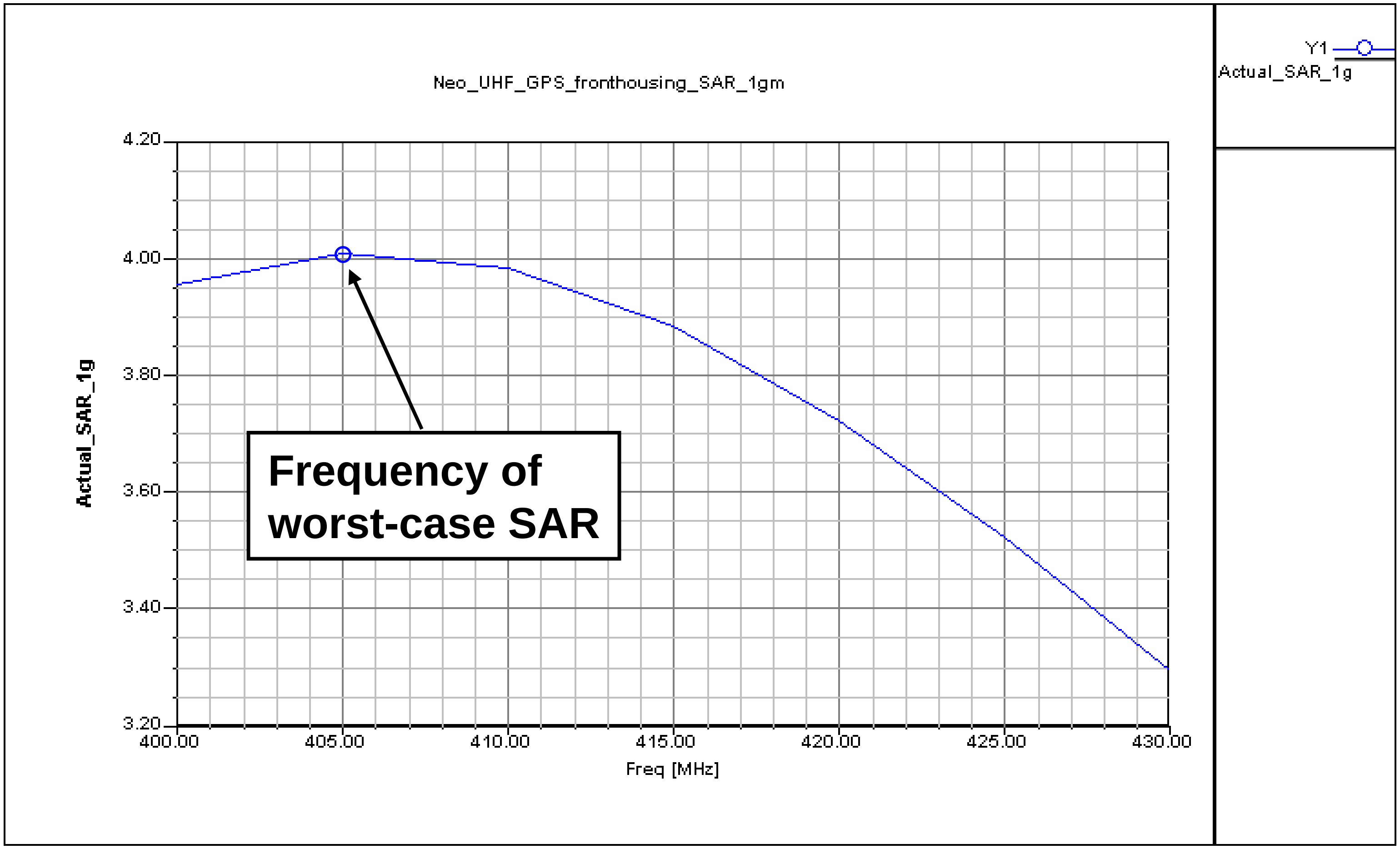
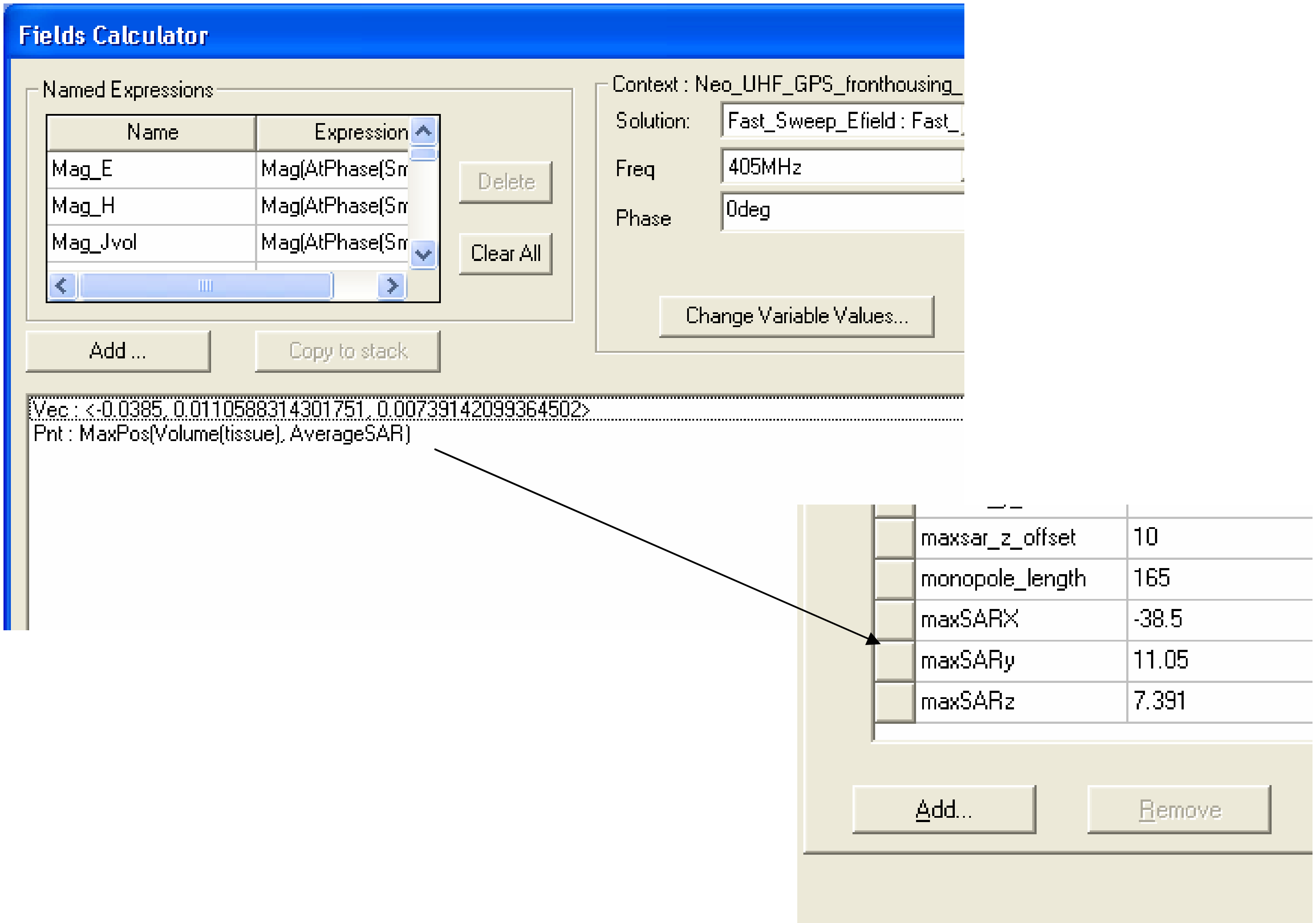
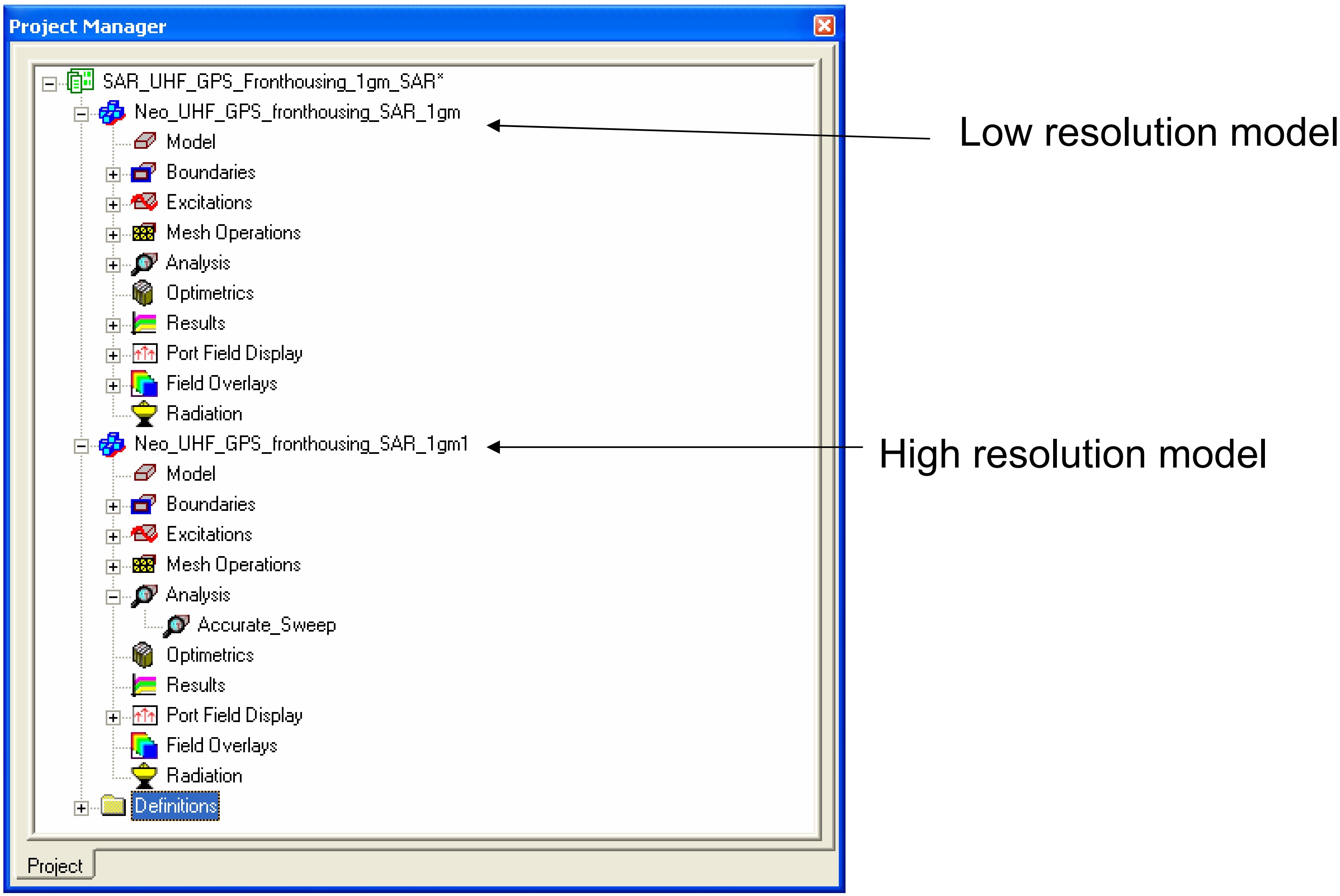
Scaled to 4.7 W with 50% duty cycle



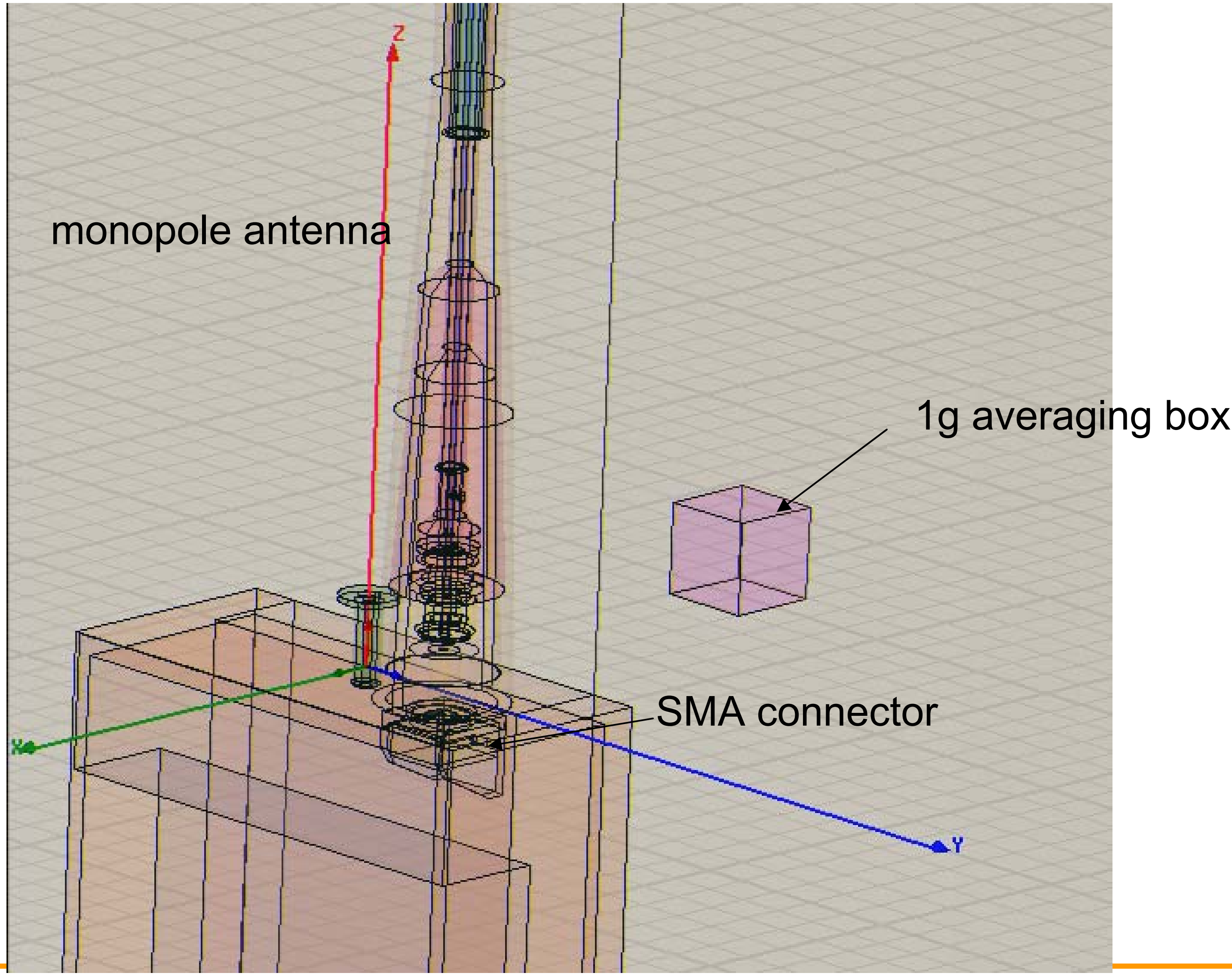
Design Stage 2: Extract position of hot spot to define the averaging box for Stage 3



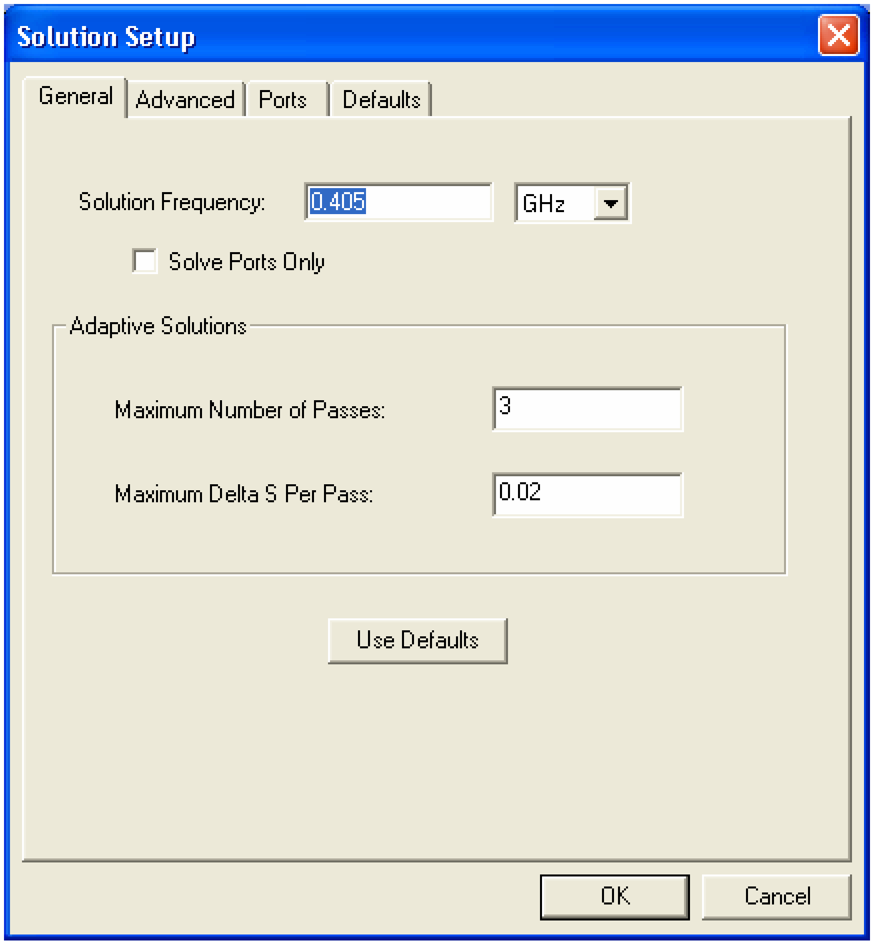
Design Stage 3: Duplicate HFSS Design

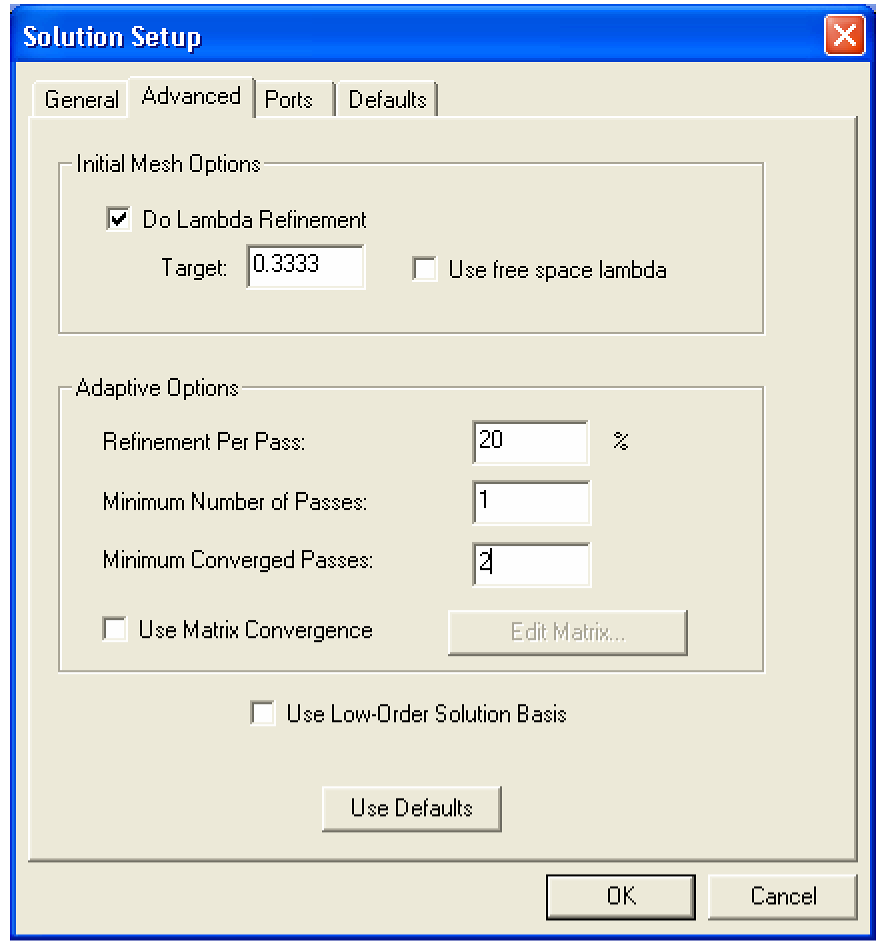


Design Stage 3: UHF Radio with SAR averaging box

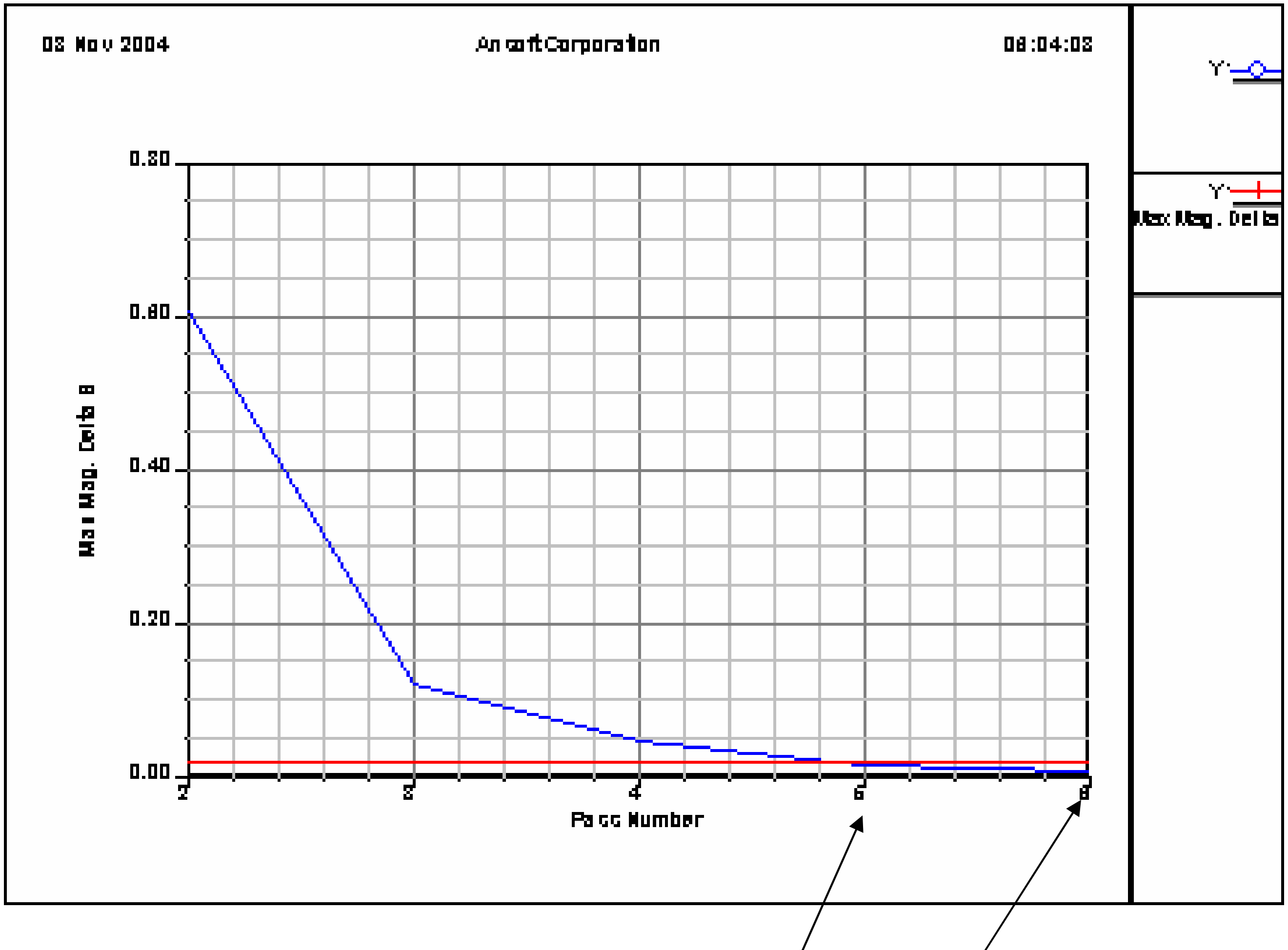


Design Stage 3: High resolution analysis setup



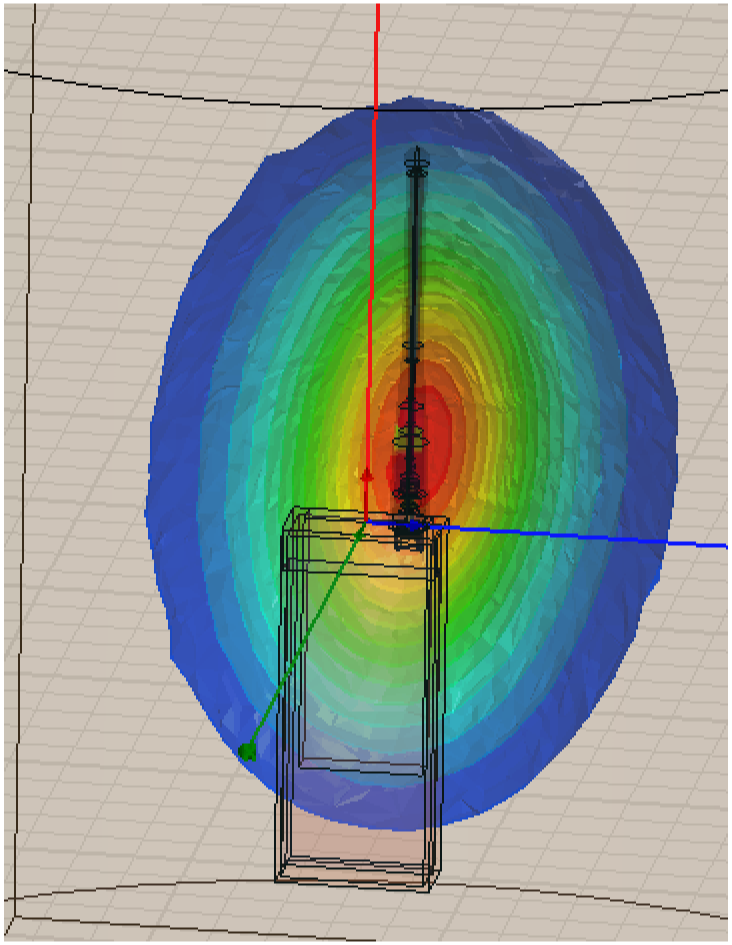


Two consecutive converged passes

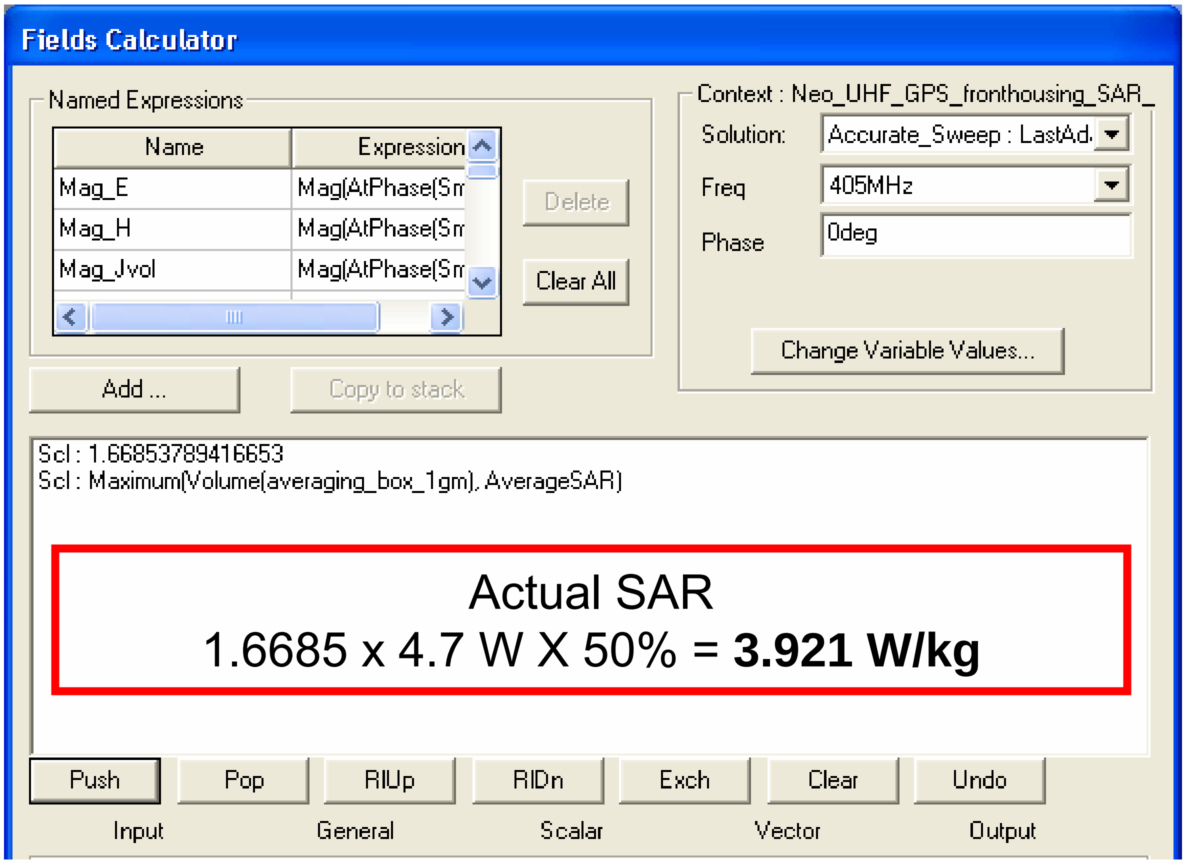


Two passes with max delta S11 of < 0.02

Design Stage 3: UHF Radio high resolution SAR at worst case frequency



Design Stage 3: Final worst-case max-avg-SAR



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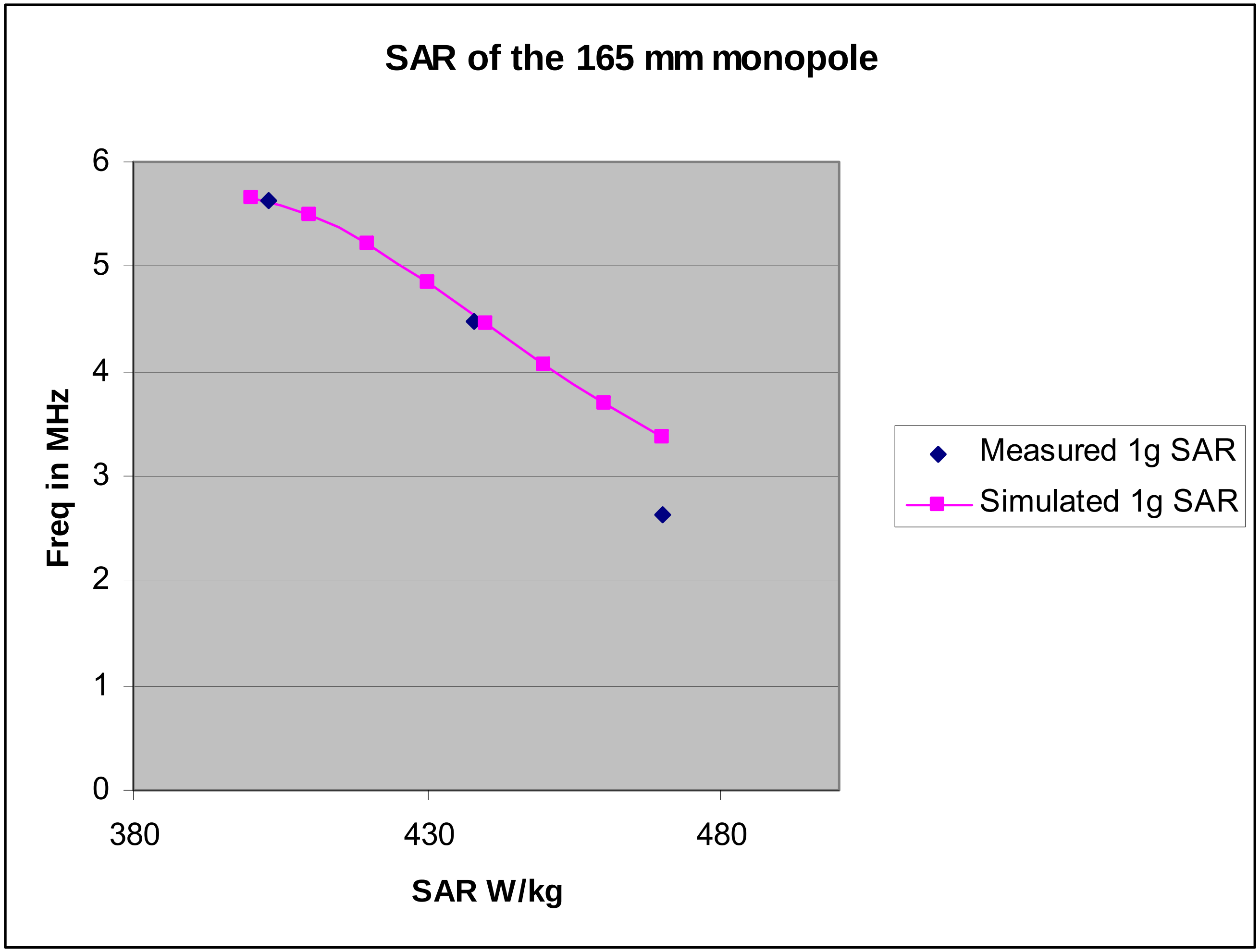
HFSS SAR Precitions Compared to Measured SAR



HFSS Analysis Profile

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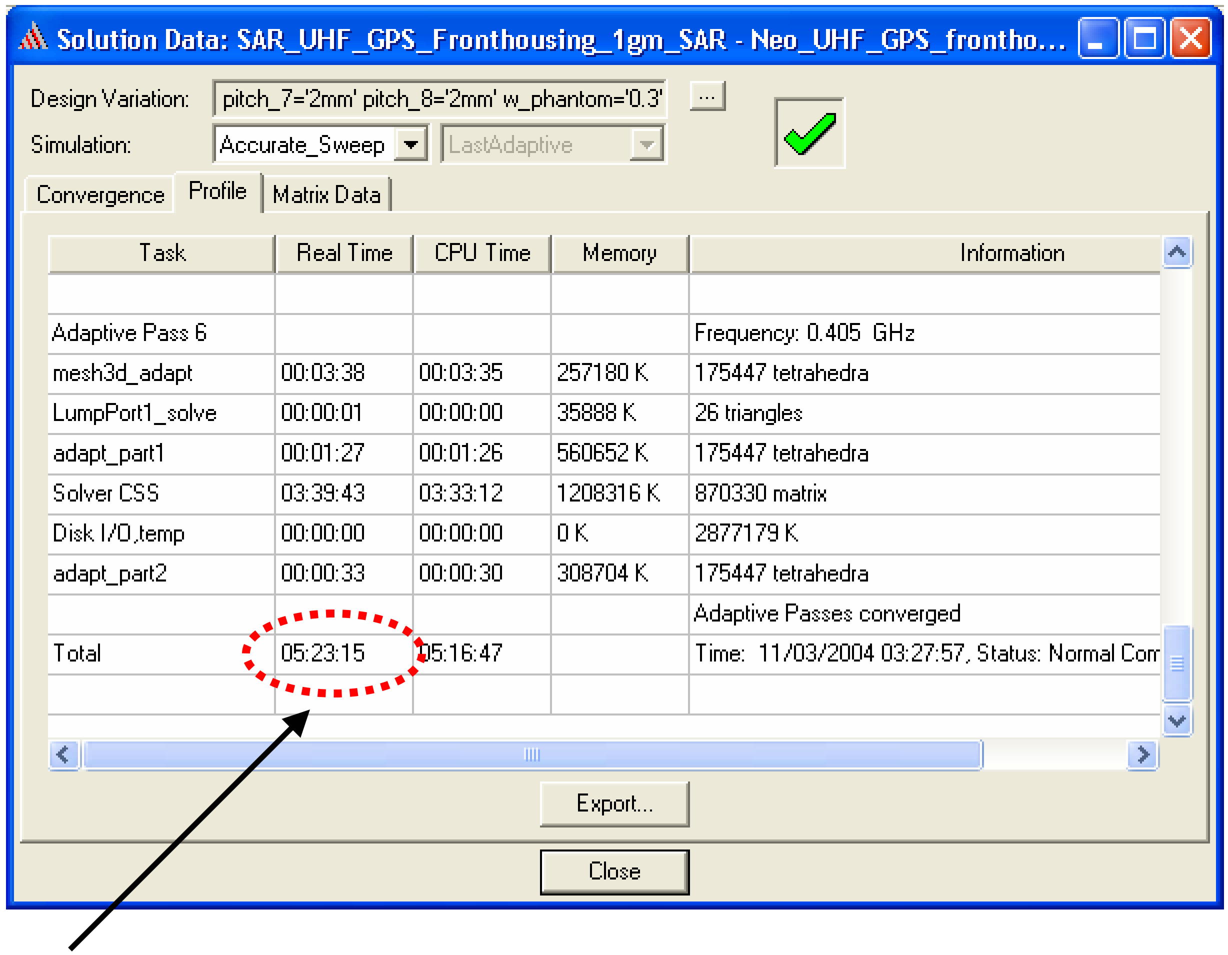

Task	Real Time	CPU Time	Memory	Information
Adaptive Pass 6				Frequency: 0.405 GHz
mesh3d_adapt	00:03:38	00:03:35	257180 K	175447 tetrahedra
LumpPort1_solve	00:00:01	00:00:00	35888 K	26 triangles
adapt_part1	00:01:27	00:01:26	560652 K	175447 tetrahedra
Solver CSS	03:39:43	03:33:12	1208316 K	870330 matrix
Disk I/O,temp	00:00:00	00:00:00	0 K	2877179 K
adapt_part2	00:00:33	00:00:30	308704 K	175447 tetrahedra
				Adaptive Passes converged
Total	05:23:15	05:16:47		Time: 11/03/2004 03:27:57, Status: Normal Com

5 hours for the high resolution analysis

reduced dramatically by new 64-bit dual processor and/or dual core CPUs

Conclusions

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- **Demonstrated successful application of a "Virtual Testbench" and associated design flow for pre-prototype SAR assessment.**
  - **demonstrated for actual radio platform and antenna**
  - **verified with SAR measurements**
- **Testbench is radio-independent.**
  - **design flow and platform/antenna re-use is enabled**
- **Testbench enables rapid monitoring of changes in SAR compliance as the radio is changed.**
  - **enables SAR compliance to be considered and tracked throughout <u>initial product design</u> for early design tradeoffs**
  - **enables proposed <u>changes to existing radios</u> to be quickly characterized within individual product groups**