# PC 03 – KBC

For each task, you can obtain 2 credits.

In the task, we are going to model a specific absorbed rate (SAR) on a wrist of an adult man. The wrist is illuminated by a **wire dipole** representing an on-body antenna at the frequency of 2.45 GHz. The input power to the antenna is 1 W. The wrist is approximated by a three-layer phantom (Fig. 1) consisting of a skin of 2 mm thickness, a muscle of the diameter of 52 mm and two bones of the diameter of 8 mm. Parameters of layers are given in Tab. 1.

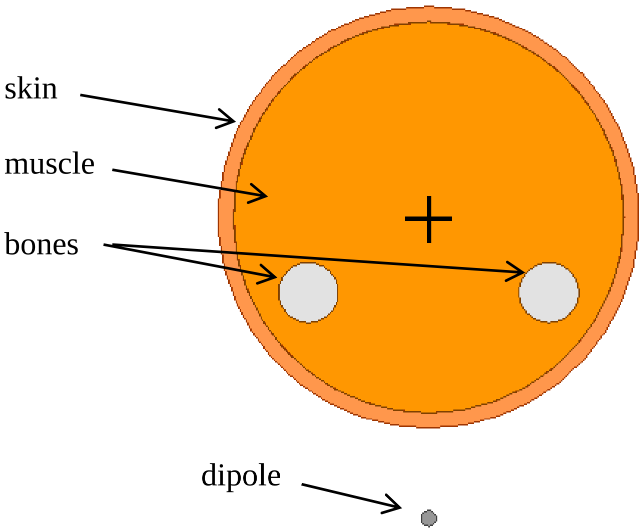


**Figure 1** Simplified numerical phantom of wrist; cut view.

| | $\varepsilon_r$ [–] | $\sigma$ [S/m] | $\rho$ [kg/m$^3$] |
|---|---|---|---|
| Bones | 11.4 | 0.39 | 1850 |
| Muscle | 54.4 | 1.74 | 1040 |
| Skin | 38.0 | 1.46 | 1100 |

**Table 1** Parameters of layered phantom at 2.45 GHz [1].

**Dipole**. The length of the arm should be $\lambda_0/4$, and the maximum width is $\lambda_0/8$. The minimum width should be 1 mm. Here, $\lambda_0$ is the wavelength in vacuum.

**Wrist**. The wrist is represented by four cylinders with the length of 60 mm. The vertical position of the bones is 10 mm under the phantom center and the horizontal offset is 16 mm to the left/right side. The phantom is placed in an air box whose all sides are set to *Radiation*. The dipole is placed 10 mm above the wrist.

**Task 1**

Dimensions of the dipole should be computed for the frequency 2.45 GHz, and parameters of the phantom should be set accordingly. Effect of the tissue on the antenna parameters should be evaluated in the frequency range of 2-3 GHz.

**Task 2**

Evaluate local SAR on the skin for the power of source of 1 W at the frequency 2.45 GHz. Averaged SAR should be evaluated over 10 g mass of tissue while a cube voxel with edge size of 1 mm is used. Find the maximum source power that meets the limit for local exposure of 4 W/kg.

**How to do it …**

1. In a new project (Project → Insert HFSS Design), create a cylinder Dipole (Draw → Cylinder) along *Z* axis symmetrically to *XY* plane for Z = 0 mm (Center Position = [0mm ,0mm ,-*dipole_l*/2]; Radius = 1 mm; Height = *dipole_l*).
2. In the center of the Dipole, create a cylinder Dipole_gap by drawing a new object or by copying the Dipole (Edit → Copy, Edit → Paste). The parameters of the Dipole_gap are Center Position = [0mm ,0mm ,-1mm], Radius = 1 mm and Height = 2mm.
3. Subtract the Dipole_gap from the Dipole (Modeler → Boolean → Subtract). Do not keep a copy of the Dipole_gap being subtracted.
4. Change the material of the Dipole from vacuum to PEC (Modeler → Assign Material).
5. Change the grid plane to *YZ* (Modeler → Grid Plane → YZ) and in the center of the Dipole, create a rectangle Port (Draw → Rectangle). The position of the Port is [0 ,-1mm ,-1mm] and Ysize and Zsize = 2 mm. After the operation, set the grid plane back to *XY*.
6. Select the Port and assigned it to the lumped port (HFSS → Excitation → Assign → Port → Lumped Port). Define a new integration line between the arms of the Dipole.

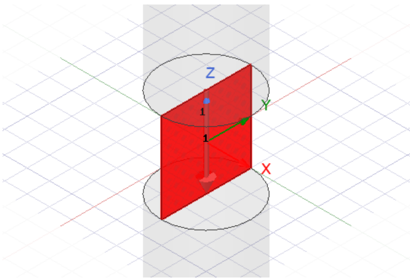


**Figure 2** Lumped port definition.

7. The Dipole has to be placed in free space. The distance *air_t* between objects and the radiation boundary condition must be at least $\lambda_0/3$. Create a vacuum box Air with Position = [-*air_t* , -*air_t* , -*dipole_l*/2-*air_t*]. The Xsize, Ysize, and Zsize are 2**air_t*, 2**air_t*, and *dipole_l*+2**air_t*, respectively. In Properties of the Air, enable Display Wireframe. Select the Air and set the Radiation boundary condition on its surface (HFSS → Boundaries → Assign → Radiation).
8. Set a new analysis at the single solution frequency of 2.45 GHz (HFSS → Analysis Setup → Add Solution Setup → Advanced). Leave the other settings unchanged, confirm by OK and in the Frequency Sweep dialog, set the frequency sweeping for 51 points in the band of 2-3 GHz. Run the analysis (Analysis → Setup1 (right mouse click) → Analyze).

9. Display the magnitude of the reflection coefficient of the Dipole.

   HFSS → Results → Create Modal Solution Data Report → Rectangular Plot →
   Solution: Setup1:Sweep
   Primary Sweep: Freq
   Y: dB(S(1,1)) → New Report

   If necessary, tune the resonant frequency by changing the length (*dipole_l*) of the Dipole.

10. Display the 3D gain pattern of the Dipole at 2.45 GHz. First define the calculation of field strengths in the far region (Radiation → Insert Far Field Setup → Infinite Sphere → OK). For the 3D gain pattern, define a new results

    HFSS → Results → Create Far Fields Report → 3D Polar Plot →
    Solution: Setup1:LastAdaptive
    Primary Sweep: Phi
    Secondary Sweep: Theta
    Y: dB(GainTotal) → New Report

11. Now, the Dipole can be placed 10 mm above the wrist. Make a copy of the project with the dipole (Ctrl+C, Ctrl+V). Create a numerical phantom using four cylinders. If the phantom is placed in the negative *X* direction, the Center Position of the Muscle should be [-10mm-*skin_t*-*muscle_d*/2 ,0mm ,-30mm]. Make sure the objects do not overlap each other. Assign material properties to the created objects (Bones, Muscle, Skin) according to Table 1.

12. The Air must include the phantom objects with the $\lambda_0/3$ condition. Change *Position* and *Size* of the Air accordingly.

13. Run the analysis and compare the magnitude of $S_{11}$ of the dipole in free space and in the proximity of the tissue (Results (right mouse click) → Copy Data).

14. Compare the radiation pattern of the dipole in free space and in the proximity of the tissue.

15. The local SAR can be shown on the selected surface. Select the outer surface of the Skin (Edit → Selection Mode → Faces) and visualize the local SAR (HFSS → Fields → Plot Fields → Other → Local_SAR → Done).

16. To visualize averaged SAR, an averaging over a cube-shaped region with homogeneous electrical properties weighing 10 g mass of tissue has to be performed (HFSS → Fields → SAR Setting → Mass of Tissue (gram) → 10 → OK).

17. The SAR value corresponds to the source value of the port (HFSS → Fields → Edit Sources).

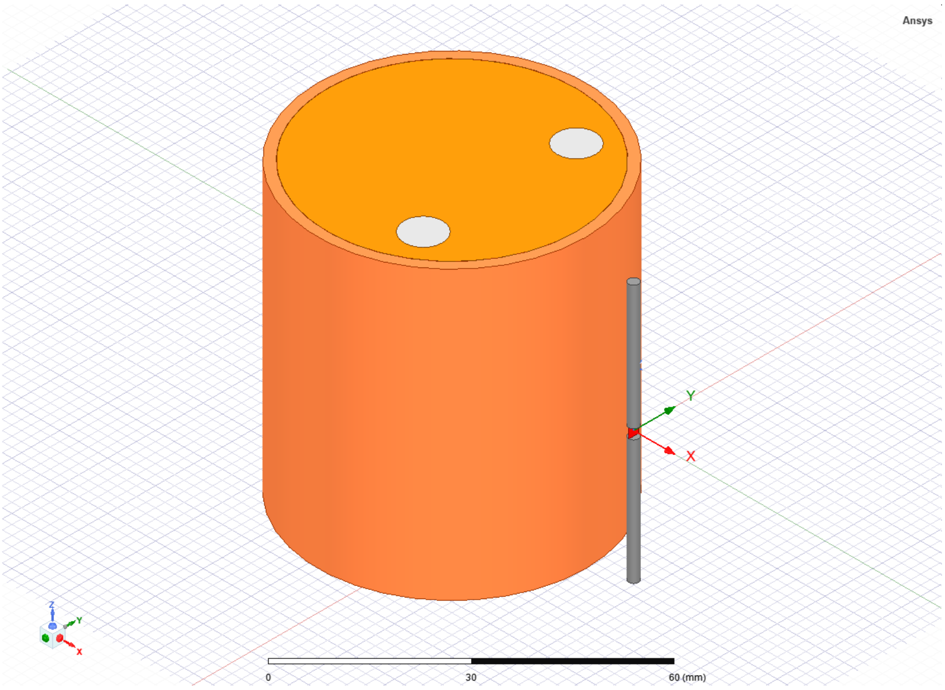


**Figure 3** Numerical model of wrist and dipole in HFSS.

## Literature

[1] D. Andreuccetti, R. Fossi and C. Petrucci: "An Internet resource for the calculation of the dielectric properties of body tissues in the frequency range 10 Hz - 100 GHz". IFAC-CNR, Florence (Italy), 1997. Based on data published by C.Gabriel et al. in 1996. [Online]. Available: http://niremf.ifac.cnr.it/tissprop/