UWB Antenna Patch in the car model by HFSS10.1 simulation

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This document summarizes the results (mainly from April to June 1, 2006; car models from February to April 2006) with the ultra-wide-band (UWB) antenna designed by Dr. Reza Rafi inside the car model.

Part 1. The car model in HFSS & FEKO

The first step of the simulation is to create a good car model in the simulation software (HFSS or FEKO).
This step has been summarized in my presentation on April 28, 2006 to Mark IV people, i.e., ***Mark_IV_Project_Report_20060428.pdf***.

1.1. Car model with Matlab

To summarize briefly, we first played with the AutoCAD .dxf formats for a BWM car model and drew its parts and whole geometry with Matlab scripts, as shown in Fig. 1 and ***Mark_IV_Project_Report_20060428.ppt***. However, we met difficulties in importing the .dxf format into the HFSS or FEKO, which do not have good support to the .dxf format although it is claimed that they can do this. We then also tried to draw the car manually in HFSS and FEKO, however, it takes too much labor work (tried in folder HFSS_DHH/20060406CarModelHFSS10.hfss).

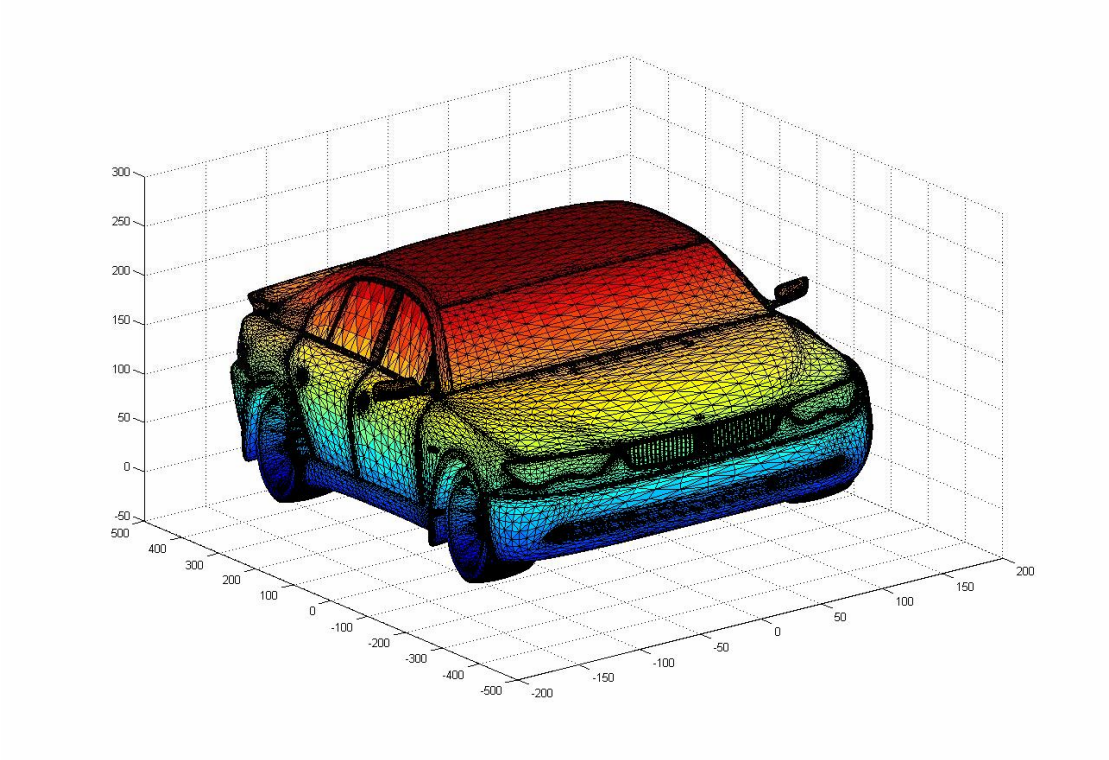


Fig. 1. The BMW car model analyzed by Matlab scripts

1.2. Car model in HFSS and plane wave simulation

Later, we obtained a .sm3 model for a car model (folder /HFSS_DHH/20060411Ansoft_Car_Model_Wang), which was studied to be of the ACIS .sat format, and imported it into the HFSS. However, FEKO needs a separate license for the importing of ACIS .sat geometries, and although we have requested this additional license for several times, we have not received it till present.

For this 3D modeler car model, we simulated it in Car2_20060411b.hfss with a incident plane wave with k vector (-1 ,-1 ,0), Eo vector (0 ,0 ,1), origin (3, 3, 0), and obtained the electric field on the cross-section plane of the car as Fig. 3.

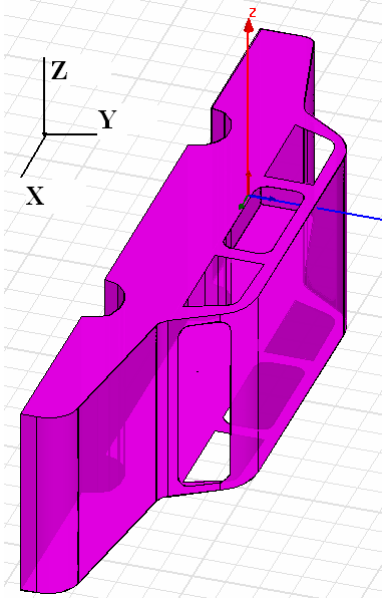


Fig. 2. Ansoft HFSS 3D modeler car model (car2.sm3), which is ACIS .sat format

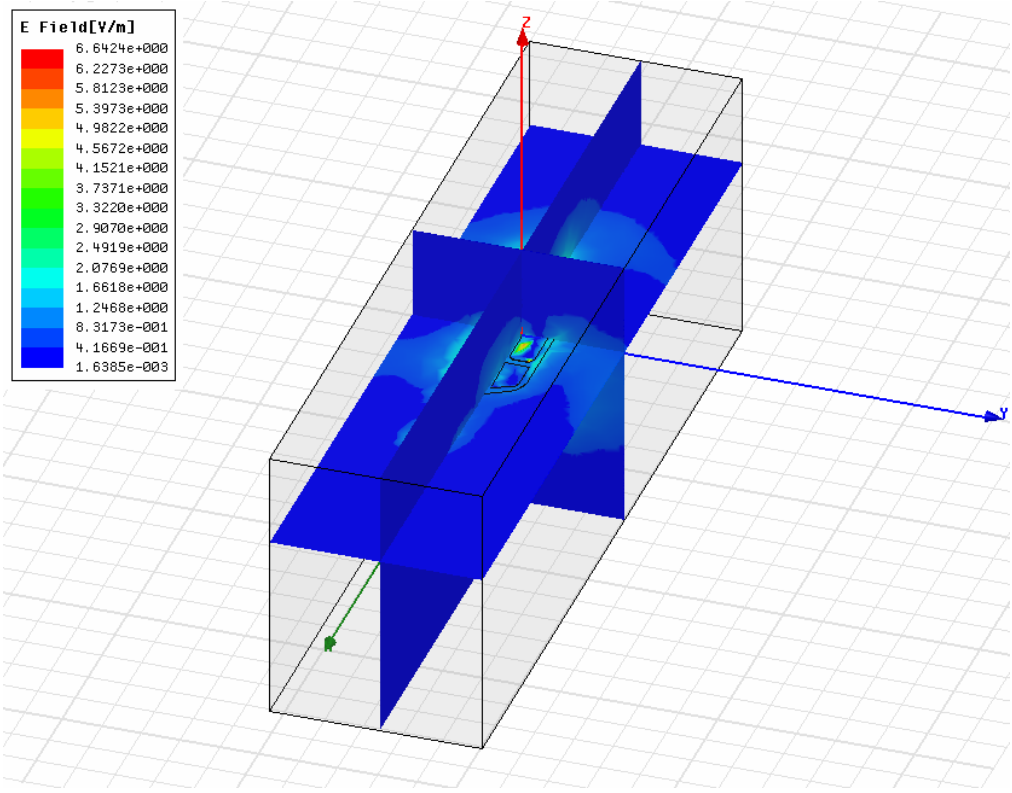


Fig. 3. The E-field on the car for a plane wave incidence

Part 2. The HFSS car model with UWB antenna patch

The second step of the simulation is to incorporate the existing ultra-wide-band (UWB) antenna patch designed by Dr. Reza Rafi (design for Giga Hertz wavelengths, 2.4G to 6G) into the HFSS car model and see how the car affects the performance of the antenna.

2.1. Antenna patch

First, in \HFSS_DHH\20060420Rafi_Antenna_Patch, we combined the design of the antenna and the car model. Then in \HFSS_DHH\20060424Antenna_In_Car\ Ant_In_Car_AtFrontMirror_20060424.hfss, we moved the antenna patch to the position where a back mirror of a car should be. We simulated the antenna in the car for the frequencies design for the original UWB antenna patch, but find that due to the significant dimension difference between the car (3 meters long) and the antenna patch (6cm*6cm), it is not able to finish the simulation on the current computers with 3G CPU processor and 2G memory. We then reduced the frequency to 900MHz, which is also a standard frequency used in wireless communications.

The simulation on f=2.4GHz (free space wavelength = 12.5cm) and 900MHz 900MHz (free space wavelength = 33.3cm) for the antenna only is carried out in Ant_Rafi_Far_Field_Mesh_20060511.hfss. The following is taken out from report ***Ant_Rafi_Car_Far_Field_20060508Result.do***c.

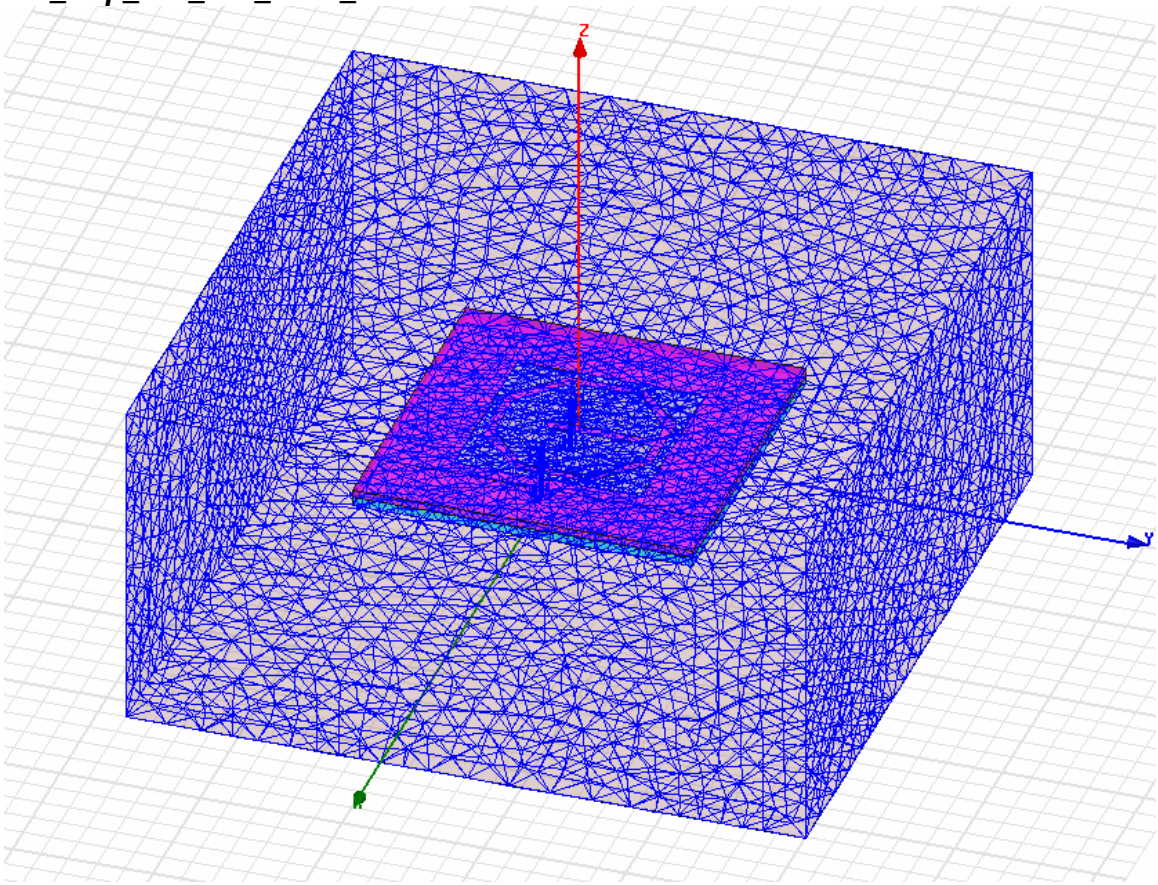


Fig. 4. The mesh for UWB patch antenna (with Mesh Options for Lengths of Antenna and Box) Ant_Rafi_Far_Field_Mesh_20060511.hfss

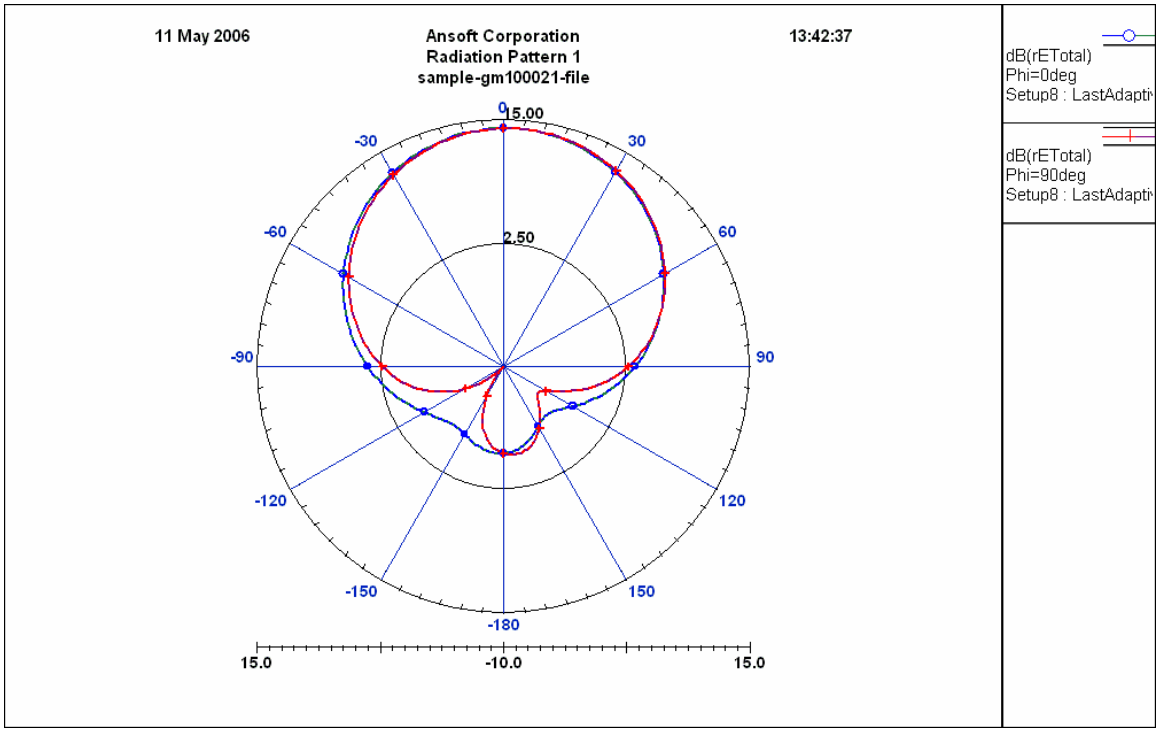


Fig. 5. The far field pattern of the antenna patch in free space (located original place (0,0,0) with f=2.4GHz) (Ant_Rafi_Far_Field_Mesh_20060511.hfss) S=(S11, S12; S21, S22)=(-0.26654+j*0.1948, -0.44152-j*0.76481; -0.44152-j*0.76481, -0.26512+j*0.19723);Z=(Z11, Z12: Z21, Z22)=(2.136+j*21.73, 0.66095-j*39.857; 0.66095-j*39.857, 2.1348+j*21.861);Port Zo = (51.415+j*0; 51.423+j*0);

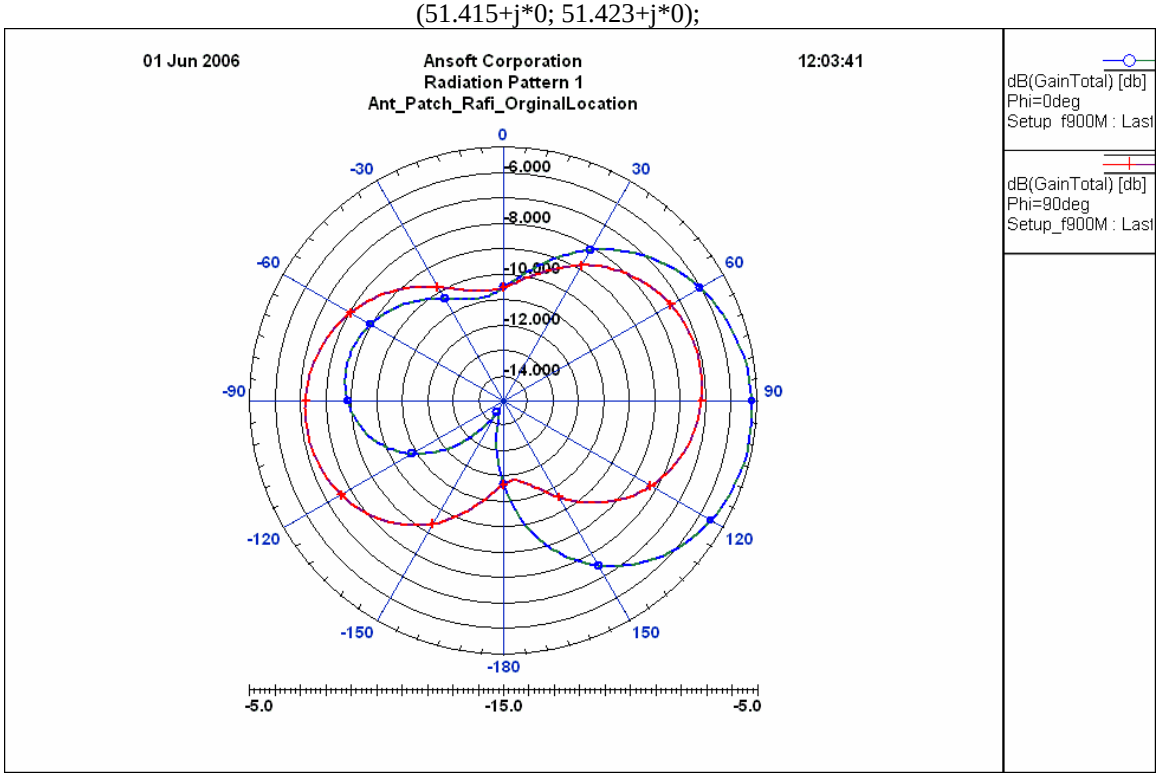


Fig. 6. The far field pattern of the antenna patch in free space (located original place (0,0,0) with f=900MHz) (2006-06-01. Ant_Car_ 20060601.hfss, "Ant_Patch_Rafi_OrginalLocation") (S=(S11, S12; S21, S22)=(-0.80307+j*0.32216, -0.18056-j*0.45903; -0.18056-j*0.45903, -0.80289+j*0.32263); Z=(Z11, Z12: Z21, Z22)=(0.10649+j*10.606, 0.075257-j*14.167; 0.075257-j*14.167, 0.10637+j*10.619); Port Zo = (51.422+j*0; 51.414+j*0);)

Since the antenna is not designed for 900MHz, later we will design a simple dipole antenna at 900MHz for the antenna in car simulation (details in ***Ant_Car_Dipole_Report_20060726.doc***)

2.2. Antenna patch in the Car (Antenna at +y direction)

We now simulate the situation when the antenna is in the car. If we do not control the mesh of the car and the radiation box to be much smaller than the wavelength, the radiation pattern of the antenna in the car is just some noises, which has been met several time in May 2006 simulations. However, the meshes are difficult to be smaller for f=2.4GHz due to computer memory limitation. Therefore, we try with smaller frequency. When the Frequency is reduced from 2.4G Hz to 900MHz (free space wavelength = 33.3cm). A typical edge size at the outer box is about 108/8=13.75cm, which is about one third of the wavelength. The following is copied from the report ***Ant_Rafi_Car_Far_Field_20060508Result.doc***.

In this calculation, the patch antenna is rotated by 90-degree so that its up face is on +y direction, and moved from the original place (0, 0, 0) to (120, 18, -60)cm so that is located at the place of the back-mirror at the car front.

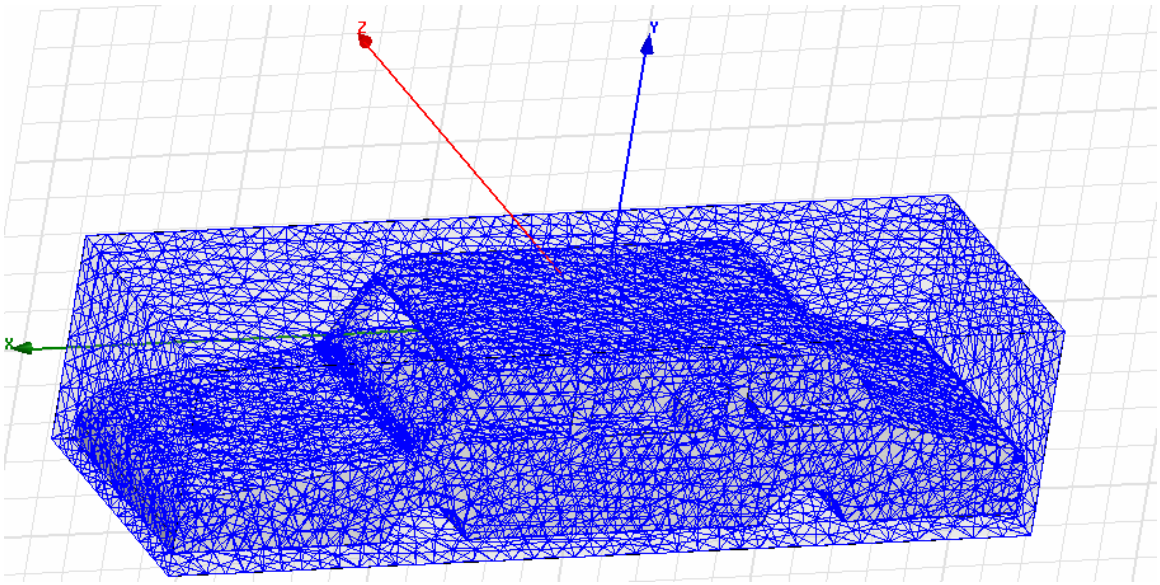


Fig. 7. The mesh of the car and the outer-box (2006-05-21: Ant_Car_20060521.hfss)

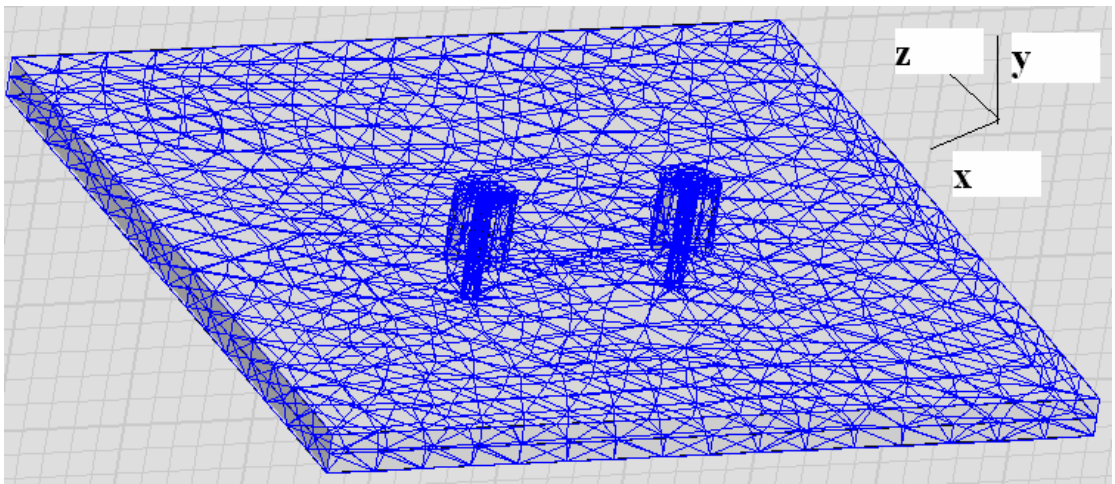


Fig. 8. The mesh of the antenna (2006-05-21: Ant_Car_20060521.hfss)

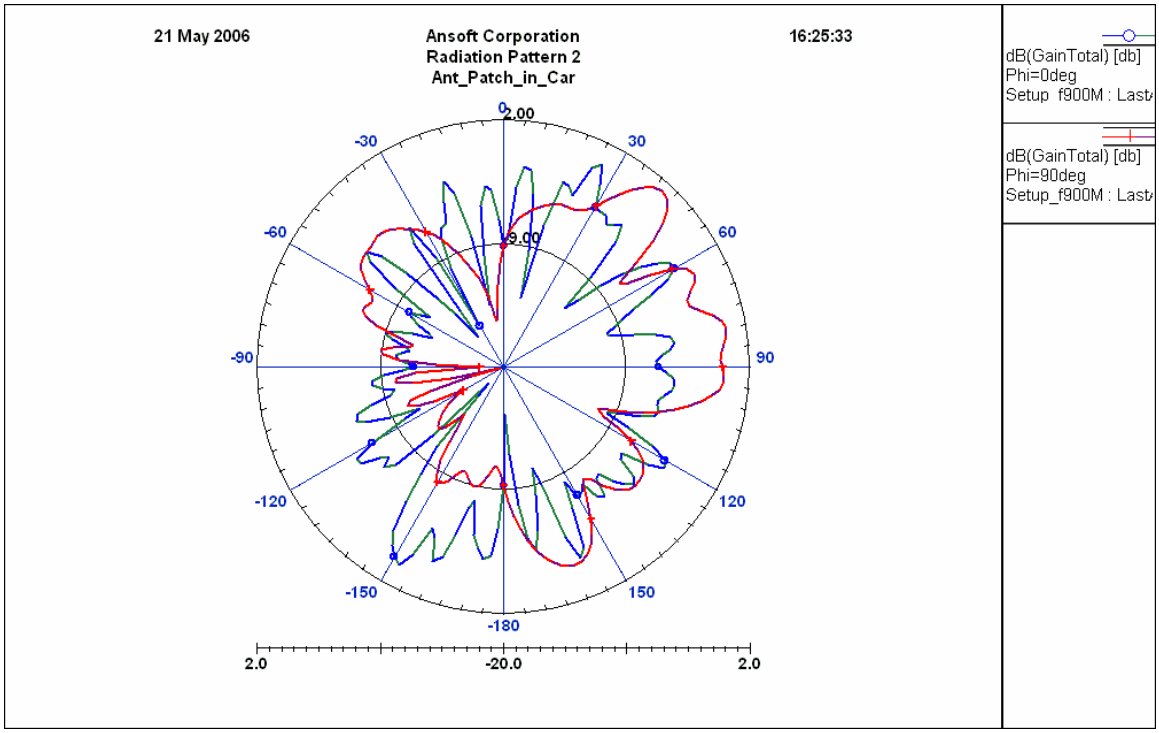


Fig. 9. The far field pattern of the antenna patch in the whole car at 900MHz (S=(S11, S12; S21, S22)=(-0.24843+j*0.18202, -0.39468-j*0.81065; -0.39468-j*0.81065, -0.26219+j*0.1414); Z=(Z11, Z12: Z21, Z22)=(1.6651+j*19.988, 0.74546-j*40.273; 0.74546-j*40.273, 1.9423+j*18.097); Port Zo = (51.432+j*0; 51.444+j*0);)

We also tried the above simulation with only a half of the car, as Fig. 10, the far field pattern is shown in Fig. 11 (copied from ***Ant_Car_half_20060524.doc***).

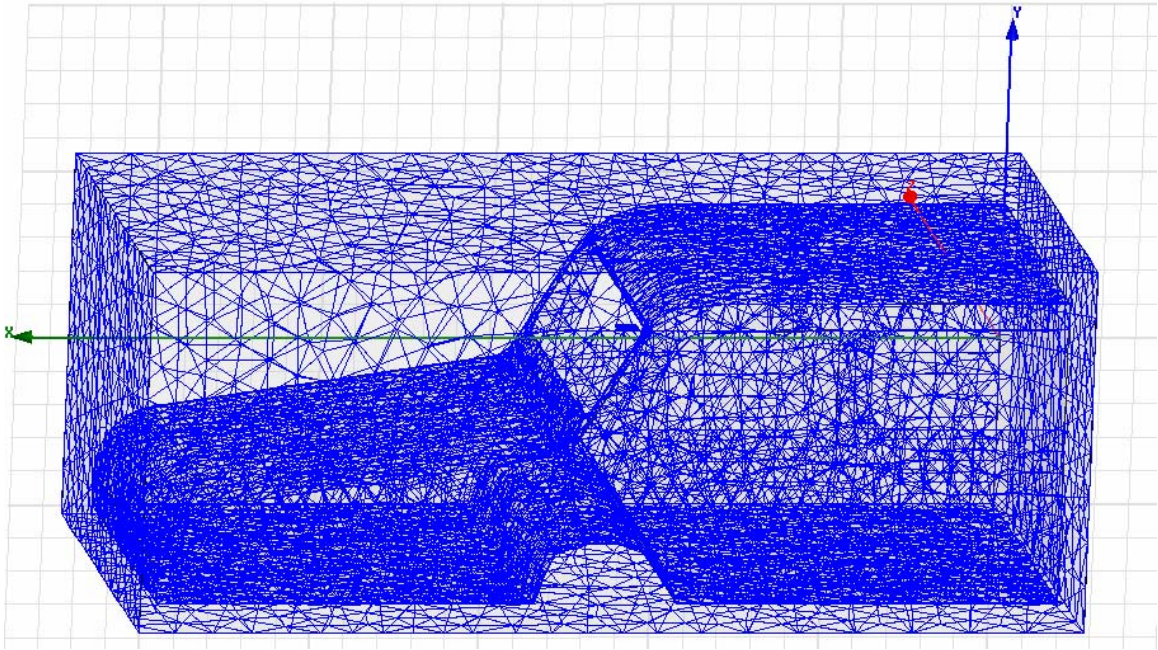


Fig. 10. The mesh of half of the car and the outer-box (2006-05-24: Ant_Car_20060524.hfss or Ant_Car_20060525.hfss)

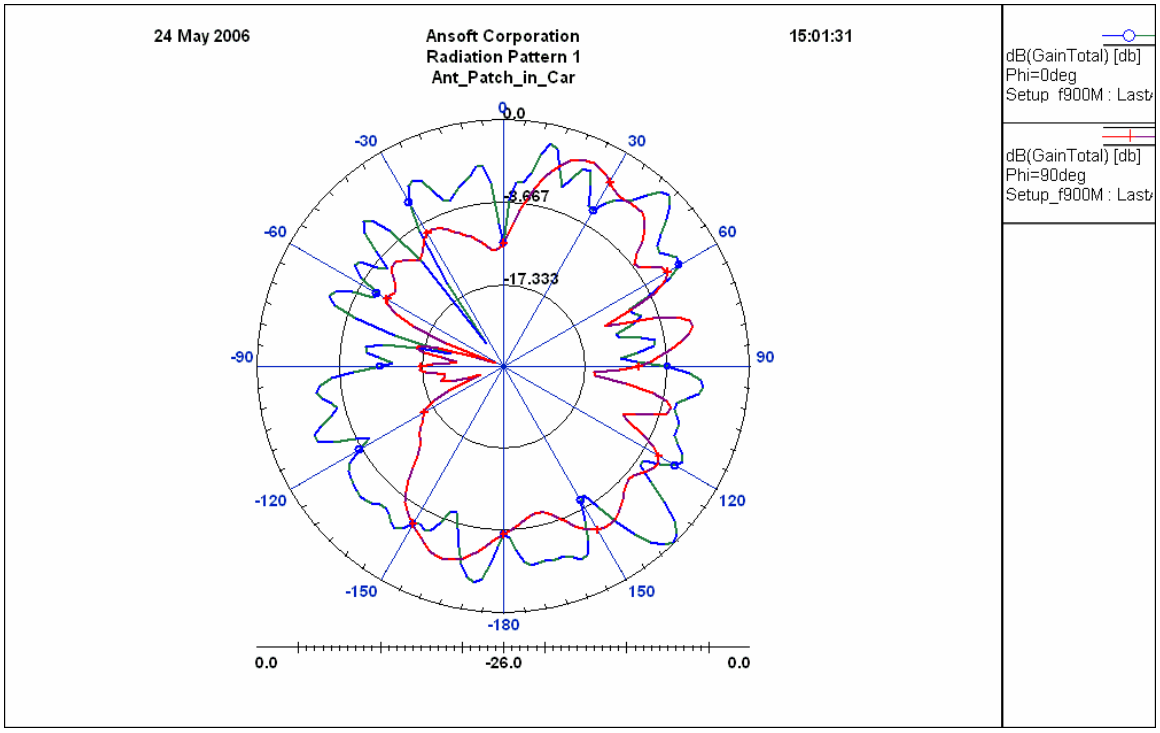


Fig. 11. The far field pattern of the antenna patch in half of the car at 900MHz (S=(S11, S=(S11, S12; S21, S22)=(-0.80495+j*0.32366, -0.1813-j*0.45787; -0.1813-j*0.45787, -0.80579+j*0.32175); Z=(Z11, Z12: Z21, Z22)=(0.063989+j*10.641, 0.043381-j*14.116; 0.043381-j*14.116, 0.06198+j*10.579); Port Zo = (51.429+j*0; 51.421+j*0);)

2.3. Antenna patch in the Car (Antenna Rotated & Half-Car)

We then rotate the antenna rotated to be approximately parallel to the front window, as Fig. 12, and compare the far field pattern for the antenna inside the car and the antenna in free space. The absolute locations of the antenna in these two cases are the same. Frequency 900MHz (wavelength is 33.3cm in vacuum). Mesh size at the out box is approximately 6.75cm (approximately one fifth of the wavelength).

(Ant_Car_Script_20060529.hfss, Ant_Car_20060529to0601.doc)

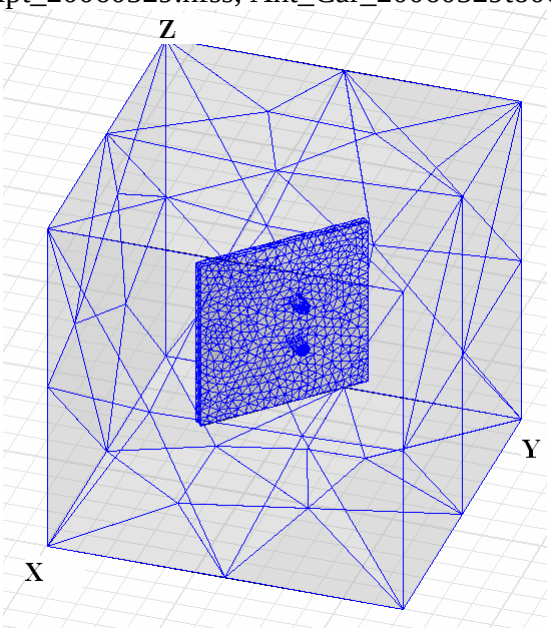


Fig. 12. The rotated antenna (normal direction at (1, 1, 0), and (120-35, 18, -60)cm, the car is moved back -35cm along x-axis)

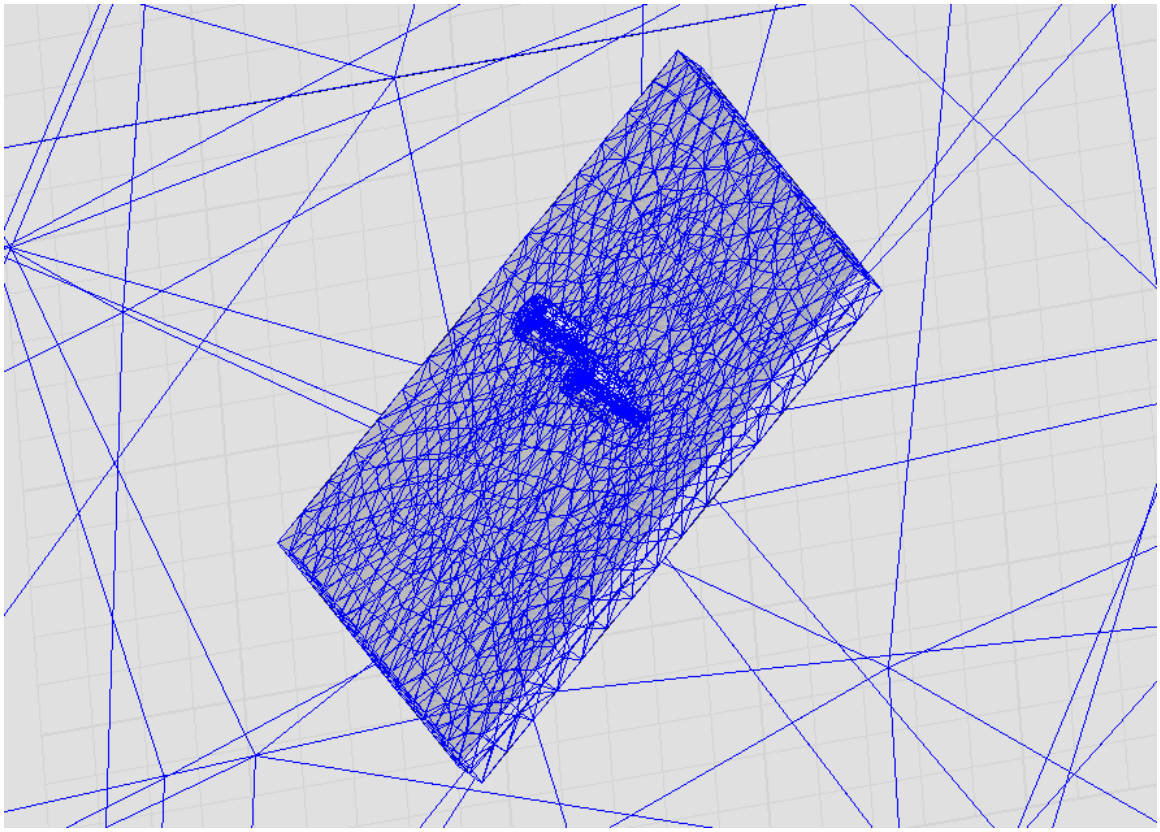


Fig. 13. The antenna rotated to be approximately parallel to the front window (Ant_Car_Script_20060529.hfss, Ant_Car_20060529to0601.doc)

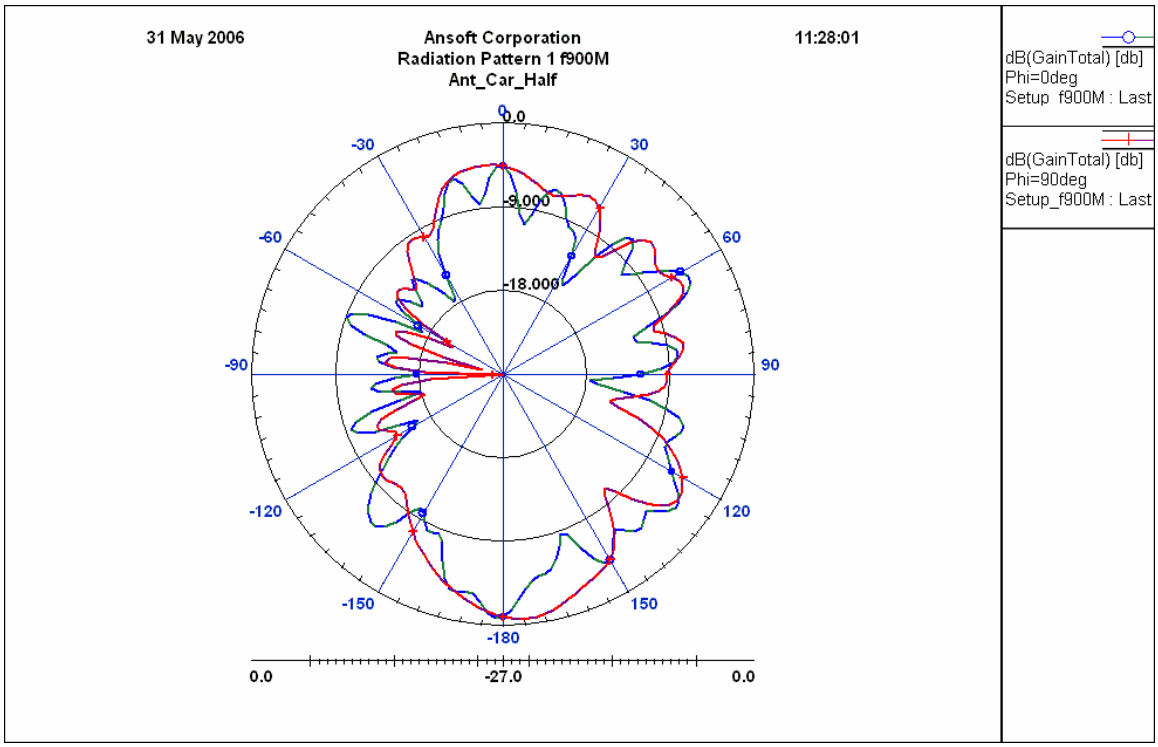


Fig. 14. The far field pattern of the antenna patch (parallel to car front window) in half of the car at 900MHz (S=(S11, S12; S21, S22)=(-0.80532+j*0.32333, -0.18189-j*0.45761; -0.18189-j*0.45761, -0.80523+j*0.32369); Z=(Z11, Z12: Z21, Z22)=(0.059238+j*10.634, -0.039061+j*14.12; -0.039061+j*14.12, 0.057921+j*10.65); Port Zo = (51.43+j*0; 51.456+j*0);

2.4. Summary of the antenna patch in the car

We summarize the S-parameter and the impedance values in Table 2.1 for Part 2 analysis with f=900MHz.

The far field patterns can be compared by Figs. 6, 9, 11, and 14 for the four cases.

f=900MHz	S=(S11, S12; S21, S22)		Z=(Z11, Z12: Z21, Z22) (Ohm)		Port Zo (Ohm)	Far field pattern
Case 1. Antenna in free space	-0.80307 +j*0.32216	-0.18056 -j*0.45903	0.10649 +j*10.606	0.075257 -j*14.167	51.422 +j*0	**Fig. 6**
	-0.18056 -j*0.45903	-0.80289 +j*0.32263	0.075257 -j*14.167	0.10637 +j*10.619	51.414 +j*0	
Case 2. Antenna (+y direction) in the whole car	-0.24843 +j*0.18202	-0.39468 -j*0.81065	1.6651 +j*19.988	0.74546 -j*40.273	51.432 +j*0	**Fig. 9**
	-0.39468 -j*0.81065	-0.26219 +j*0.1414	0.74546 -j*40.273	1.9423 +j*18.097	51.444 +j*0	
Case 3: Antenna (+y direction) in the half car	-0.80495 +j*0.32366	-0.1813 -j*0.45787	0.063989 +j*10.641	0.043381 -j*14.116	51.429 +j*0	**Fig. 11**
	-0.1813 -j*0.45787	-0.80579 +j*0.32175	0.043381 -j*14.116	0.06198 +j*10.579	51.421 +j*0	
Case 4. Antenna (rotated) in the half car	-0.80532 +j*0.32333	-0.18189 -j*0.45761	0.059238 +j*10.634	-0.039061 +j*14.12	51.43 +j*0	**Fig. 14**
	-0.18189 -j*0.45761	-0.80523 +j*0.32369	-0.039061 +j*14.12	0.057921 +j*10.65	51.456 +j*0	

Part 3. The Dipole Antenna (900MHz) in the car model

This is summarized in the report document (***Ant_Car_Dipole_Report_20060726.doc***):
\HFSS_DHH\20060713Ant_Car_Dipole_Script\Ant_Car_Dipole_Report_20060726.doc

The HFSS file used is Ant_Car_20060718.hfss.