**Lab 2: Microstrip Patch Antenna**

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| **Introduction：**  In this experiment, we focus on the modeling and feeding mode of the microstrip patch antenna, and using HFSS to conduct modeling and parameter analysis of the microstrip patch antenna. In the after-class task of this experiment, we designed a microstrip patch antenna fed by a 1/4 wavelength converter, and made the antenna work in 2.4GHz frequency band by calculating various parameters. Through parameter analysis and parameter optimization, the performance of the antenna we designed can meet the requirements.  **Lab results & Analysis：**  **Question:**  Design a microstrip rectangular patch antenna with microstrip line feed using HFSS for operating at 2.4 GHz. Plot its S11, Gain, radiation efficiency, Radiation pattern.  **Result & Analysis:**  **Model Diagram and Simulation Setup:**  20220308124431  Figure 1 The overall model  20220308124534Figure 2 Port configuration  20220308124840  Figure 3 Air box setup(Transparent cube)  **Notes：**In this experiment, determining the size of the air box and how to model the air box is an interesting problem. Here, we can choose the size of the air box to be greater than 1/4 of the operating wavelength. Therefore, the size of the air box I choose in this experiment is 40mm.20220308145707  Figure4 The dimensions of the air box  20220308124950  Figure 5 Set the frequency sweep range  **Parameter list:** **(After Optimization)**  20220308125026  Figure 6 All parameters in the model (after optimization)  **Analysis：**  In this antenna design, the most difficult part lies in the selection of the length and width of the radiation patch. In the following part, I will focus on how to calculate the length and width of the radiation patch under the circumstances of a given working frequency band.  Through consulting relevant materials, we have obtained the following design guidelines:  20220308125615  Figure 7 Method for determining the size of radiation patch  20220308130330  20220308130526  Figure 8 Determination of equivalent impedance(Rin) of radiation patch  20220308131605  **Note: We generally default Z1 to 50 ohms**  Figure 9 Determination of characteristic impedance of 1/4 wavelength converter  Therefore, through the above design guide, combined with MATLAB, we can write a calculator to calculate the length and width of radiation patch and the characteristic impedance of 1/4 wavelength converter, the code is as follows:(We assume that the thickness of the microstrip line we design is 2mm and the dielectric constant is 2.2)  clear; clc;  c = 3e8;  f = 2.4e9;  er = 2.2;  h = 2e-3;  W = c/(2\*f)\*sqrt(2/(er+1)) %辐射贴片的宽度  er\_eff = (er+1)/2 +(er-1)/2\* (1+12\*h/W)^(-0.5); %有效介电常数的计算  dL = (0.412\*(er\_eff+0.3)\*(W/h+0.264)\*h) / ((er\_eff-0.258)\*(W/h+0.8)); %计算等效的辐射缝隙长度  L\_eff = c/(2\*f\*sqrt(er\_eff));  L = L\_eff - 2\*dL %计算实际的辐射贴片长度L    %微带线馈电的贴片天线  lambda\_0 = c/f;  if W<= lambda\_0  G = W^2 / (90\*lambda\_0^2);  else  G = W^2 / (120\*lambda\_0^2);  end    Y\_in = 2\*G;  R\_in = 1/Y\_in %计算出天线贴片的等效阻抗  Z\_T0 = sqrt(R\_in\*50) %计算出1/4变换器的等效阻抗  By running the program, we can get the length and width of the radiation patch, the equivalent impedance of the radiation patch and the 1/4 wavelength converter, as shown below:  20220308131304 20220308131308  Figure 10 Determination of the length and width of radiation patch(Left figure), characteristic impedance of radiation patch and 1/4 wavelength converter(Right figure)  Therefore, at this point, the relevant parameters of the radiation patch are all determined. Next, we need to determine the width of the 1/4 wavelength converter and the 50 ohm feeder. (Since the width is related to the characteristic impedances of the 1/4 wavelength converter and the 50 ohm feeder, the length of the 50 ohm feeder depends on the size of the microstrip line we modeled) Here, we can easily determine the two widths using a microstrip calculator or ADS, as shown below:20220308132451  Figure 11 Determination of length and width of 1/4 wavelength converter  20220308132734  Figure 12 Determination of the width of the 50 ohm feeder  So, at this point, all the parameters related to this design have been determined, and the next step is our modeling process, as shown in the figure above.  **Optimization:**  The S-parameter image is a key point of this experiment simulation. The antenna we designed should have the minimum S parameter image at the 2.4GHz frequency point. If the above parameter Settings are followed, we found that the minimum value (valley value) of the antenna we designed was slightly deviated from 2.4GHz. Therefore, we need to optimize the length and width of the radiation patch.  20220308133204 | |
| 20220308133437  Figure 13 The Optimization of the dipole length  Finally, after optimization, the width of the radiation patch is 51.013317668mm, and the length is 39.7101194873mm.  **Simulation results:**   1. **S-parameter**   **20220308133742**  Figure 14 S-parameter image of this antenna  As can be seen from the above image, the S11 parameter of the antenna reaches a minimum value at 2.4GHz, which proves that the working performance of the antenna designed by us meets the requirements of the question.   1. **Gain**   **20220308133936**  Figure 15 Gain total curve of this antenna   1. **Peak & Realized Gain**   **20220308134109**  Figure 16 Peak directivity/gain and Realized gain curve of this antenna  As can be seen from the figure above, when the operating frequency is near 2.4GHz, the images of realized gain is almost coincide with those of peak gain. This proves once again that the antenna has a very small reflection and good working performance at 2.4GHz.   1. **Radiation Efficiency**   **20220308162550**  Figure 17 Radiation efficiency of antenna  As can be seen from the figure above, the radiation efficiency of our designed antenna reaches the peak value at 2.4GHz and the value is near to 1, which once again confirms that the performance of our designed antenna meets the corresponding requirements.   1. **Radiation Pattern**   **5.1 Gain Total**  **20220308134326**  Figure 18 The Gain total radiation pattern of this antenna**(phi = 0 deg)**  **20220308134342**  Figure 19 The Gain total radiation pattern of this antenna**(phi = 90 deg)**    **5.2 Gain Phi and Gain Theta(Co-pol & Cross-pol)**  **20220308134503**  Figure 20 The Gain phi and Gain theta radiation pattern of this antenna**(phi = 0 or 90 deg)**  **Experience**  In this experiment, we deepened the modeling process of HFSS and designed a microstrip patch antenna fed by a 1/4 wavelength converter. The most complex design in this lab is the determination of radiation patch and 1/4 wavelength converter parameters, through consulting relevant information and write their own MATLAB program, I finally determined these parameters successfully. Of course, there are always some deviations between the theoretical calculation and the actual simulation results, so after the first simulation, we need to optimize the length and width of the radiation patch according to the image of S11. After optimization, we can simulate the other parameters of the antenna, and the results show that the parameters and indexes of the antenna designed by us can better meet our design requirements. | |
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